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On the Organisation of the Fossil Plants of the Coal-Measures. Part XV

William Crawford Williamson

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III. *On the Organisation of the Fossil Plants of the Coal-Measures.*—Part XV.

By William Crawford Williamson, *LL.D., F.R.S., Professor of Botany in the Owens College, Manchester.*

Received June 13,—Read June 21, 1888.

[Plates 1–4.]

Some years ago M. Renault described* some specimens of petioles of Ferns, which he identified with Corda's genus *Zygopteris*, identical, in part, with Cotta's genus *Tubicaulis*. In my memoir, Part VI.,† I described, from the lower Carboniferous rocks of Lancashire, two of M. Renault's species, viz., *Zygopteris Lacattii* and *Z. bibractensis;* but, from an unwillingness to multiply genera based only upon the ill understood fragments of imperfectly known plants, I proposed (*loc. cit.*, p. 677) the provisional adoption of the neutral generic term *Rachiopteris* for a considerable number of these objects, which appeared to be either rhizomes or petioles of Ferns. Subsequent researches have, I think, shown the wisdom of doing so; at all events, further discoveries, which I now propose to put on record, unmistakably confirm my opinion.

In the same memoir (*loc. cit.*, p. 173) M. Renault described a rhizome, with petioles, the latter of which closely resembled those of Corda's genus *Anachoropteris*, and to which the French palæontologist gave the name of *Anachoropteris Decaisnii*. But the structure of the rachis of this plant, especially of the transverse section of its vascular bundle, was wholly different from that of any plant previously observed. Having obtained a stem identical with this *Anachoropteris*, but without any petioles connected with it, I figured my specimen in my memoir, Part VI., Plate 58, fig. 51, where I described it as closely resembling M. Renault's *Anachoropteris Decaisnii*.

It must be remembered that Corda's two genera, *Anachoropteris* and *Zygopteris*, were solely based by him upon distinctions between the transverse sections of two petioles. That author knew nothing of the nature of the rhizome of either of these petioles. M. Renault, however, obtained a rhizome associated with a petiole closely identical with that of Corda's *Zygopteris*, which he described* under the name of *Zygopteris Brongniartii*. He thus possessed Corda's two forms of petiole asso-

* 'Annales des Sciences Naturelles,' 5ième Série, *Bot.*, vol. 12, 1869, p. 161.

† 'Phil. Trans.,' vol. 164, 1874.

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ciated with two distinct, though not wholly dissimilar, rhizomes. The French *savant* described the two genera *Zygopteris* and *Anachoropteris* as distinguished primarily by the differences between these petioles, but secondarily by the differences between their rhizomes.

In my memoir, Part VIII. ('Phil. Trans.,' vol. 167, pp. 217 *et seq.*), when describing a new rhizome and its petioles, under the name of *Rachiopteris corrugata*, I gave at some length my reasons for not multiplying generic names for these curious plants; pointing out how wholly impossible it was to classify recent Ferns on any such basis, a fact the importance of which is further illustrated by the rhizome which I am about to describe.

Some weeks ago, my young auxiliary collector, Mr. LOMAX, to whom I was indebted for the Calamitean fruits described in my last memoir, Part XIV., brought me a specimen having the central vascular axis of M. RENAULT'S *Anachoropteris Decaisnii*, with petioles of the true Zygopteroid type: thus demonstrating that the axis found by RENAULT in connection with a petiole of CORDA'S type of *Anachoropteris* was equally the axis of a Zygopteroid petiole. The specimen has been a drifted fragment, now imbedded in a hard ganister full of Goniatites.

Fig. 1 (Plate 1) shows the five-rayed transverse section of the vascular axis of the stem or rhizome; at a is a vacant spot, occupied in some sections by a delicate parenchyma—obviously a medullary one—five thin prolongations of which, a', a', are projected into five rays of the vascular axis b. This axis is composed of a mass of scalariform tracheids. Each centrifugal ray first contracts in diameter, and then expands again, terminating in a truncated, more or less bifurcated extremity. The maximum diameter of this axis from the tip of one ray to that of another is rather more than a quarter of an inch. At b' the end of one of these rays is detached, apparently to form the vascular centre of a lateral appendage. At c is a thin band of structure superficially resembling a bundle-sheath; a similar investment encompasses not only the central axis, but each of the separate organs.† Apparent rootlets are seen at d.

Fig. 2 is a second transverse section through the vascular axis, b, of a specimen like fig. 1, from which it differs only in one or two respects. Thus, the detached bifurcate end resembling that of the ray b' of fig. 1 is replaced at fig. 2, b', by a cylindrical vascular bundle, ·05 of an inch in diameter, whilst the corresponding one at b'' has disappeared; between the bundle b' and its investing zone, c, are remains of cellular parenchyma. The black masses e, e are the carbonised remains of the cortical parenchyma.

Fig. 3 is part of another section like fig. 2, but in which the circular section of a

* *Loc. cit.*, Plate IV., fig. 4 *bis*, and Plate V., fig. 5.

† In a recent memoir, to be referred to on a later page, Professor STENZEL, of Breslau, describes specimens which show that these bands do represent zones of specialised, more or less sclerous, cortical tissue.

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lateral appendage like b' of fig. 2 reappears at e, but is now enclosed within an entire and separate circle of the tissue fig. 2, c, at c'. The supposed rootlets are also seen at d, and the carbonised cortical tissue at e. But outside the circular aberrant organ b' we now have a transverse section of a large Zygopteroid petiole. The H-shaped section of the vascular bundle of this petiole is seen at f, surrounded by a ring of the structure c at c'.

Fig. 4 represents a more perfect specimen of a similar Zygopteroid petiolar bundle, in which several of the tissues are well preserved. In the slenderness both of its central portion f and its two transverse ones f', f'', this vascular bundle approaches nearer to RENAULT'S *Zygopteris bibractensis* than to any of the other forms hitherto described. In this specimen the cellular tissue of the cortical parenchyma is fairly well preserved, even in the dark masses, and is beautifully so at the two more central portions e', e'. The anomalous zone c entirely invests this vascular bundle, like an endodermal zone.

Fig. 5 is a small detached vascular axis found close to a section like figs. 1 and 2. In its centre there exists a small vacant spot, a, from which there diverge four radiating lines, apparently repeating, on a small scale, the configuration of a, a in figs. 1 and 2. Fig. 5A is obviously a structure identical in its contour with fig. 3, e, but the middle of its central bundle approximates to fig. 5A. We have a point a, from which radiate three lines, a', corresponding to a' of figs. 1 and 2. These two examples, fig. 5, and especially 5A, seem to suggest that, whilst the organs figs. 3 and 4, f, are destined to become true petioles, those of figs. 2, b', and 3, e, indicated by b', b' are destined to become ordinary branches of the rhizome, like the centres of figs. 1 and 2. The vascular axis of each of these circular structures is obviously destined ultimately to assume the pentagonal form of that of the primary stems.*

* On January 12th of the present year, I received from Professor STENZEL, of Breslau, a copy of an interesting memoir by him, entitled "Die Gattung *Tubicaulis*, COTTA." In this memoir the author figures and describes some examples of COTTA'S genus, and of *Asterochlæna*, *Anachoropteris*, and *Zygopteris* of CORDA. He sub-divides *Asterochlæna* into the sub-genera *Meriopteris*, *Asterochlæna*, and *Clepsydropsis*, and the genus *Zygopteris* into *Zygopteris* and *Ankyopteris*. Under the name of *Zygopteris* (*Ankyopteris*) *scandens*, this author describes and figures a plant which appears to me to be identical with my *Rachiopteris Grayii*. In this plant Dr. STENZEL finds the organ which I have represented in fig. 2, b', and fig. 3, e, in exactly the same position as I have done, viz., between the exterior of the main stem and the superior or posterior side of the petiolar bundle, fig. 3, f. He also regards it, as I have done, as a young state of a stem or branch; giving to it the apparently appropriate designation of an *axelsprosse*. His specimens further show that the dubious investing zones of the several organs which I have indicated in my several figures by c and c' are not mere mineral developments, but represent zones of tissue, often of a sclerenchymatous character, as I have already pointed out. He also thinks, as I have concluded, that the organs d, of my figures 1 and 3, are true roots or rootlets. These agreements between two independent observers are, of course, satisfactory. As to the specific name of the plant, since my memoir was received by the Royal Society on June 13th, 1888, whilst Professor STENZEL'S memoir has only been published during the present year, my name of *Rachiopteris Grayii* will have the precedence, unless Professor STENZEL has given the name to his plant in any earlier publication.—February 12th, 1889.

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The exterior of the cortex of this plant was densely clothed with hairs. Though longitudinal sections through the specimen described present a somewhat obscure arrangement of tissues and organs, these hairs enable us to distinguish external surfaces from internal structures. The difficulty of doing this is the greater since two distinct stems are pressed closely together in the fragment of ganister in which my specimens are preserved, and also from the fact that the innumerable small cylindrical organs, *d*, variously intersected, and each with an ill preserved vascular bundle in its interior, abound in all my preparations both within the cortex, and externally to it, as at *d*, *d*. Similar structures appear to exist in M. Renault's specimens of *Anachoropteris*, but that observer regards them as representing petiolar bundles. Mine, like his, are ill preserved; but they more closely resemble adventitious roots than petiolar structures. A similar one M. Renault himself regards as a "racine adventif." These organs are about ·066 of an inch in diameter.

That no classification of these fossil Ferns based *solely* upon the transverse sections of their petiolar bundles is or can be of much value, is clearly shown when tested amongst those living Ferns the classification of which is chiefly based upon their sporangial reproductive organs. But, I think, I can show that we have here to do with a type of stem-structure which is remarkable, and which appears to throw them into something like a natural group recurring in several allied plants.

In his memoir above referred to, M. Renault describes and figures* a transverse section of the stem of his *Zygopteris Brongniartii*. In this section we find a central structure "très probablement cellulaire" "ou à ses prolongements qui, au nombre de six dans le *Zygopteris*, s'enfonçaient plus ou moins dans l'épaisseur de l'étui ligneux *a*, *a*, formé par les cellules scalariformes." (*Loc. cit.*, pp. 164–5.)

Specimens in my cabinet confirm M. Renault's suggestion that this central structure, with its thin radiating arms, is really a cellular one, being either a medulla or of a procambial character—but apparently the former—associated in either case with peculiarities in the primitive development of the vascular bundle which surrounds it. The presence of this peculiar cellular centre within the vascular axis constitutes a feature which seems to unite several otherwise distinct plants into a common group. It is obviously identical with the structure *a*, *a'*, seen in my figs. 1, 2, and 5 of the present memoir. In my memoir, Part VIII.,† I figured, under the name of *Rachiopteris corrugata*, transverse sections of a stem which has a structure almost identical with that of M. Renault's *Zygopteris Brongniartii*, and in which the central cellular structure sends off five or six radiating and sometimes dichotomosing arms, partially subdividing the surrounding vascular cylinder into half-a-dozen groups of cells. Unlike M. Renault's similar example, the petiolar bundles given off by this central axis are not Zygopteroid in form, since they lack the two parallel extensions *f'*, *f''* seen in Plate 1, fig. 4, of the present memoir; what

* Plate 3, fig. 1.

† 'Phil Trans.,' vol. 167, Plate 5, fig. 4, and Plate 6, fig. 13.

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remains corresponding apparently to the portion *f* of the same figure. In my previous memoirs I have pointed out the fact that all these Zygopteroid bundles give off alternately from the exterior of each of the two parallel portions *f′*, *f″* a considerable mass of vascular tissue, each of which detached portions usually subdivides into two parallel secondary bundles.* The *Rachiopteris duplex*, also described and figured (Part VI., 'Phil. Trans.,' vol. 164, Plate 55, figs. 28 and 35), exhibits the same phenomena, and must also be regarded as one of the Zygopteroid group; and it is more than probable that my *Rachiopteris insignis*, figured in Part VI., Plate 16, figs. 19, 20, and 21, may be regarded as connecting the petiole of *Rachiopteris corrugata*, already referred to, with the Zygopteroid type. The *Rachiopteris duplex* also appears, so far as its petiole is concerned, and especially from the mode in which the vascular bundles of the secondary petioles are detached from those of the primary one, to have corresponding affinities with the same type.

It is obvious, on the one hand, that we cannot retain both CORDA'S genera of *Zygopteris* and *Anachoropteris*; and, since the type of petiole which may be designated Zygopteroid is the more remarkable one of the two, and appears to have several other Carboniferous Fern-petioles closely allied to it, it seems desirable that M. RENAULT and those who wish to multiply these generic names should accept the genus *Zygopteris* and abandon that of *Anachoropteris* as too ill-defined to be of any real value. Personally, I prefer not to multiply these generic names until we obtain a more definite knowledge of structural identities and differences upon which generic groups can be based. Hence, I shall continue for the present to use my own provisional term of *Rachiopteris*; and, since the structure of the petiole of the plant just described is obviously sufficiently different from that of the *Anachoropteris Decaisnii* of M. RENAULT to distinguish it specifically, I shall designate the former plant *Rachiopteris Grayii*, in memory of my lamented friend, ASA GRAY.†

Returning to my figures of the petioles of *Rachiopteris duplex*,‡ it will be observed that the two secondary bundles *a*, *a*, given off in alternate pairs from the opposite sides *a′*, *a′* of the primary petiolar bundle *a*, obviously supply the two secondary petioles *y*, *y*, giving off, in their turn, smaller bundles to a third series of branches or pinnules. Fig. 6 of Plate 2 of the present memoir represents a transverse section of a petiole of *Rachiopteris Lacattii*,§ for which I am indebted to Mr. LOMAX, of

* See memoir, Part VI., Plate 57, figs. 45, *a″* and fig. 47, *m*, *m*.

† A further ground for abandoning M. RENAULT'S duplicated generic names is found in the fact that twice in his memoir (*loc. cit.*, pp. 165 and 177) he considers that *Zygopteris* is distinguished from *Anachoropteris* by having six of the radial prolongations of the medulla, whilst *Anachoropteris* has only five. My plant just described, which certainly should belong to M. RENAULT'S genus *Zygopteris*, has but five.

‡ Memoir, Part VI. (*loc. cit.*), Plate 65, figs. 35D and 35E.

§ In the memoir referred to on page 157, Professor STENZEL expresses an opinion that the petiole which in previous memoirs, as in the present one, I have identified with RENAULT'S *Zygopteris Lacattii* is really the *Z. elliptica* of the French author. This, however, is a mistake easily explained. In its middle cortex, M. RENAULT'S *Z. Lacattii* contains numerous gum-canals, which are not found in his

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Radcliffe, and in which the same bifurcation of the secondary pinnules is seen at y, y, each branch being supplied with a secondary fibro-vascular bundle a', from which a bundle of a third order a'' is given off, as in *Rachiopteris duplex*. This mode of dichotomous branching of secondary pinnules is clearly incompatible with fronds of the ordinary pinnate or bipinnate types. The plant must have had some more distinctive contour. The lowest secondary pinnules of several forms of *Pteris*, *e.g.*, *P. umbrosa* and *P. serrulata* branch in this quasi-dichotomous way. M. ZEILLER has figured in his 'Études des Gîtes Minérales de la France.—Bassin Houiller de Valenciennes,' two Carboniferous Ferns that distinctly branch in this manner, viz., *Mariopteris latifolia* (*loc. cit.*, Plate XVII., and *Diplotemma Zeilleri Stur*, Plate XVI.).

The additions I have made from time to time to our knowledge of the organisation of the interesting fructification, *Calamostachys Binneyana*, have left but few lacunæ in that knowledge to be filled up. Two points, nevertheless, have as yet been obscure, viz., the distribution of the vascular bundles in the central axis of the strobilus and the nature of the peripheral terminations of the fertile bracts or sporangiophores. Figs. 7 and 8 of Plate 2 throw light on both these points.

Fig. 7 is a slightly oblique transverse section through an axis of *Calamostachys Binneyana*, in the centre of which, a, is a quasi-medullary cellular parenchyma more or less invested by scalariform vessels at b, b'. At the points b, b, these tracheids are few in number, but at the four angles b', b' they are much more numerous; especially so in other strobili in my cabinet where such points approximate to the nodes of the axis.

Fig. 8 represents one of the finest tranverse sections of this *Calamostachys* I have obtained. In it a represents the central axis corresponding to fig. 7. This centre is invested by the cortical zone, k. The fertile sporangiophores appear at v, and their much-thickened peripheral extremities are seen at v'. At the points v'', v'' accumulations of tracheids appear. On comparison of this figure with that given on Plate 54, fig. 23, of Part XI. ('Phil. Trans.,' 1881), it will be seen that these clusters of tracheids are concentrated in the immediate neighbourhood of the point v''' of that figure, *i.e.*, where each sporangium, u, is organically united to the thickened end of the sporangiophore, u'. It thus appears that these peripheral terminations of the sporangiophores approach even nearer than they were previously known to do to those of the living Equisetums, in corresponding parts of which similar clusters of tracheids exist. At g, g are transverse sections of the bracts of the next inferior verticil of the sterile organs, and at g', g' tips of a yet lower verticil of similar organs.

On studying a number of slides prepared for me by my active auxiliary, Mr. ISAAC EARNSHAW, of Oldham, I found in several of them sections of fragments of a

Z. elliptica. In the specimens which I first described, this part of the cortex had invariably disappeared. But I have more recently obtained specimens in which this inner cortex, with its characteristic gum-canals, is preserved; as is also the case in the specimen described above, where the layer in question is indicated by b.—February 12th, 1889.

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plant differing materially from any that I have hitherto described. The fragments are very Protean in form and structure, though possessing certain remarkable features in common.

Fig 9 (Plate 3) represents one of the most characteristic of these. It is a section of a branching stem or rhizome of the plant enlarged 14 diameters. At A the section has crossed a branch obliquely, revealing a central vascular axis, *a*, composed of very fine vessels of the reticulated or pitted type, some of which are fully ·01 of an inch in diameter. The inner cortex, *b′*, is composed of longitudinal lines of parenchymatous cells with transverse septa. At B is a bifurcating branch, with its vascular axis *a* also bifurcating, composed of a dense mass of vessels partly barred, but some of which are reticulate, like those of A, *a*, though of smaller diameter, some of them not being more than ·00125 of an inch in diameter. The inner cortex, *b″*, resembles that of A, *a*, but the cells are of much smaller dimensions. More externally we have at *b′* a dense cortical zone composed of elongated prosenchymatous cells. A small branch with a central vascular bundle appears to have been given off vertically at *c*; there seems to have been a similar one at *d*, and there may possibly have been a third at *e*. F is obviously a tranverse section of either a branch or a root, the vascular bundle of which occupies its centre surrounded by an inner cortex, enclosed within a more dense external one. The two external surfaces, *g′* and *g*, are densely clothed with numerous very large, curved multicellular hairs. The basal cells of some of these hairs are fully ·005 of an inch in diameter, whilst some of them are fully ·014 of an inch long. Conspicuously cylindrical throughout the greater part of their length, they are tapering, slender. Fig. 10 furnishes a carefully drawn representation of these hairs, as they appear at B *g*, *g′*, enlarged 43 diameters.

Fig. 11 (Plate 2) is a transverse section of one of these stems enlarged forty-four diameters, its mean one being ·009 of an inch. In its centre, *a*, is a cluster of tracheids, the entire cluster being about ·02 of an inch in diameter, enclosed within *b*, which appears to occupy the position of a true bundle-sheath. These tracheids are reticulated like those of fig. 9. A narrow zone of delicate parenchyma, *c*, lies between the tracheids and the supposed bundle-sheath, which may either have a circumferential phloëm or a procambial tissue. The inner cortex, *d*, consists of a very regular thin-walled parenchyma, which, in turn, is invested by *e*, a coarser prosenchymatous tissue. Externally to this prosenchyma are numerous transverse isolated sections of hairs, *f*, of varying diameters. The most striking feature of this section consists of the remains of four radiating appendages *g*, *g′*, *g″*, *g‴*. The most perfect of these is *g*, in which we discover the central vascular bundle *a* invested by the two cortical layers *d′* and *e′*. These radiating appendages, taking their rise from what has been either the pericambium or the endoderm, and forcing their way through the cortical tissues of the primary axis without receiving any contributions from those tissues, can, I think, only have been either roots or secondary rootlets.

Fig. 12 is an oblique transverse section through a stem similar to fig. 11, the lower

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end of which displays features identical with those of the latter figure. It exhibits three of the radiating rootlets (?) *d*, *d*, and *d′*; but *d′* is fortunately intersected transversely, and enables us to identify several isolated transverse sections of these roots scattered through some of my slides, three of which are figured in figs. 13, 14 (Plate 4), and 15 (Plate 1).

Fig. 13 has a mean diameter of ·0025 of an inch; fig. 14 of ·01, and fig. 15 of ·025. In each of these examples we have the conditions seen in fig. 11, *g*, viz., a central bundle, *a*, invested by the two cortical zones *d′* and *e′*, as well as the apparent bundle-sheath *b*, enclosing the phloëm *c*. In fig. 15, which seems to represent a younger but smaller rootlet, the separation of the cortex into two zones is less distinct than in figs. 13 and 14. Its component cells also exhibit the tendency to arrange themselves in the concentric cycloidal circles so common amongst young rootlets of this character. The vascular bundles of all these rootlets are of the diarch type, though possibly they may also be regarded, both in structure and development, as resembling the concentric bundles of Lycopodiaceous stems.

This plant, which I propose to distinguish as *Rachiopteris hirsuta*, is wholly distinct from any which I have hitherto described. Can it be identified with any living type? The young branches of the living *Marsileæ*, *M. quadrifolia* and *M. salvatrix*, are clothed with hairs absolutely identical with those of fig. 10, and longitudinal sections of these branches display similar irregularities of ramifications to those shown in fig. 9; rootlets, branches, and bases of fronds being alike cut through in sections made in almost any one plane, and their rootlets also remind us strongly of those seen in figs. 11, 12, 13. Without attaching an undue importance to these resemblances, the sections of *Rachiopteris hirsuta* undoubtedly suggest closer relationships with the *Marsileæ* than with any other living plants with the organisation of which I am familiar. The specimens described are from the Halifax deposits.

I have at various times discovered other forms of roots or rootlets in these Halifax Carboniferous beds, some of which at least are sufficiently interesting to be put upon record, as showing the early period at which certain types of these organs made their appearance on the earth. The first of these I discovered in some slides also prepared for me by Mr. Isaac Earnshaw, of Oldham.

Fig. 16 (Plate 4) represents a longitudinal section through a very delicate root, of which I have a number of fragments. Their most characteristic feature resides in the circumstance that their secondary rootlets are given off in numerous verticils, *c*, *c*. The cellular parenchyma of which they consist exhibits extremely limited differentiation. A primary vascular bundle, *a*, composed of barred vessels, runs down the centre of the primary axis; and secondary ones, composed of vessels of smaller dimensions, *a′*, *a′*, bend downwards and outwards into the secondary rootlets. The parenchyma, *b′*, immediately surrounding the primary bundle consists of long, narrow, thin-walled cells, which are invested by an external bark, *b*, composed of a larger and more strongly marked form of parenchyma.

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I have several transverse sections of this root in my cabinet, one of which is represented in fig. 17 (Plate 4). In its centre is a vascular bundle, *a*, having a somewhat irregular triangular section. This is invested by a zone of delicate parenchyma, *b*. An enlarged representation of the transverse section of this bundle is given in fig. 18 (Plate 3). On the upper side of fig. 17 are long sections of five, *c*, *c*, *c*, *c*, *c*, of the radiating secondary rootlets of the vertical axis from the cortical layer *b'*, of which they are extensions. Two similar specimens indicate that there were from ten to eleven rootlets in each such verticil. As the cells of the cortex *b* are prolonged into each rootlet they become elongated radially. Fig. 18 indicates that the central bundle of fig. 17, here further enlarged, is a triangular one. Fig. 19 represents a similar bundle of another transverse section like fig. 17, and enlarged equally to fig. 18. It exhibits in a similar way the bundle *a*, surrounded by its investment of either procambium or phloëm. It is obvious, therefore, that the transverse section of the primary bundle of this root was triangular, presenting at least all the essential characteristics of a triarch root. I would distinguish this plant, which, like that last described, is also from Halifax, by the provisional name of *Rhizonium verticillatum*.*

Whatever may be the case with figs. 17 and 18, I think there can be no doubt that fig. 20 is a transverse section of a true triarch root, enlarged 42 diameters. Fig. 21 represents the centre of the same section still further enlarged; *a* is a triarch vascular bundle; *b*, a concentric phloëm; *d*, cycloidally arranged cells of the cortex.

Fig. 22 (Plate 3) is an oblique transverse section of a cylindric rootlet of another description; at *a* a few vessels or tracheids occupy the centre of a mass of delicate elongated cells, either representing phloëm or procambium. The middle cortex, *b*, consists of a loose form of parenchyma, enclosing numerous irregular large lacunæ of the type so common in the roots of the Nymphæe. Of course, this indicates no systematic relation with the latter plants, beyond the fact that our fossil root most probably belonged to some aquatic or semi-aquatic type. At *c* is a compact quasi-epidermal investing layer of cells. The specimen, which is from one of the Oldham nodules, may be designated *Rhizonium reticulatum*.

Fig. 23 (Plate 3) is a somewhat larger rootlet, also with a lacunar cortex. A strongly defined vascular cylinder, *b*, encloses a delicate medullary parenchyma *a*, and is invested by a compact zone consisting of several cycloidally arranged rows of

* I was at first inclined to include these root-like objects in my provisional group of *Rachiopteris*; but, since they present few or no indications of being either rhizomes or petioles, I have determined to utilise Corda's term *Rhizonium* for them. Corda's objects, to which he gave this generic name, he appears to have regarded as being probably the roots of Orchidaceous plants; but they are really undistinguishable from the rootlets of *Stigmaria ficoïdes*. Corda's definition of his genus, "Radiculæ parasiticæ, intertextæ, cortice parenchymatosa; fasciculo vasorum solitaris centrali vagina propria incluso" ('Flora der Vorwelt,' p. 46), is, with the exception of the two first adjectives, fully applicable to my plants.—February 12th, 1889.

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endodermal cells, *c*. Numerous thin vertical plates, *d*, chiefly but a single row of cells in thickness, radiate from the zone *c* to the thicker peripheral one *f*, encircling numerous large, radially-disposed lacunæ. Every feature of this apparent root reminds us of the structure of the cortex of *Asterophyllites Williamsonis*, described in my memoir, Part XII.* Whether or not the two belong to the same plant cannot at present be determined. The specimen, which is from Halifax, may be named *Rhizonium lacunosum*.

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Plate.	Fig.		Pages on which references are made to the figures.
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1	4	Section of a well preserved Zygopteroid petiole, like fig. 3 : *f*, the central bar of its vascular bundle ; *f′*, *f″*, its transverse bars ; *c*, an investment of the	

* ‘Phil. Trans.,’ 1883.

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Plate.	Fig.		Pages on which references are made to the figures.
		tissue *c* of figs. 1 and 2 : *g*, carbonised cortical parenchyma. Cabinet number, 1818. × 7	157
1	5	A small detached vascular axis having the appearance of being metamorphosed into a structure like the axis *b* of fig. 1 ; *a*, its incipient medullary centre, with traces of four radiations, like the five *a*, *a*, of fig. 1. × 11	157
2	5A	A transverse section of a cylindrical appendage, like fig. 3, *e*, but in the centre of the vascular axis, *e*, is a point from whence radiate three lines apparently identical with the five, *a′*, *a′*, of fig. 1. Cabinet number, 1830. × 67	157
2	6	Transverse section of a petiole of *Zygopteris Lacattii* : *y*, *y*, its division into two secondary petioles ; *a*, central vascular bundle of the petiole ; *a′*, *a′*, secondary vascular bundles supplying the two branches, *y*, *y* ; *a*,″ *a*″, vascular bundles destined for ternary branches or pinnules. Inner cortical layer with gum canals, *b*. Cabinet number, 1181. × 2	159
2	7	Slightly oblique section through the central or vasculo-medullary axis of *Calamostachys Binneyana* : *a*, medullary parenchyma ; *b*, *b*, a few peripheral barred vessels : *b*,′ *b′*, clusters at each of the four angles containing large numbers of barred vessels or tracheids. Cabinet number, 1004. × 15	160
2	8	A transverse section of strobilus of *Calamostachys Binneyana* : *a*, central or vasculo-medullary axis ; *k*, coarse outer cortex ; *v*, fertile sporangiophores ; *v′*, enlarged shield-like extremities of these sporangiophores ; *v*,″ *v*,″ accumulations of tracheids within the peripheral margins of these shield-like expansions and near the points at which the sporangia, *u*, are united to the sporangiophores ; *g′*, *g*,′ tranverse sections of the sterile bracts forming the next inferior verticil of these organs ; *g′*, *g′*, sections of the upper	

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Plate.	Fig.		Pages on which references are made to the figures.
		parts of a still lower verticil of the same organs. Cabinet number, 1000. × 40.	160
4	9	A section through a branching fragment of *Rachiopteris hirsuta*: A, oblique longitudinal section through a portion of a stem or branch; *a*, a large vascular bundle composed of beautifully reticulated or pitted vessels; *b*, *b′*, cortical layers; B, a second bifurcating branch of the same group; *a*, the vascular axis also dichotomosing and composed of a mixture of barred and reticulated vessels or tracheids, the latter resembling those of A, *a*; *b*, the inner cortex corresponding to A, *b″*; *b′*, outer cortex, like A, *b*; a zone of somewhat thickened prosenchymatous cells; *c*, a transverse section of a small lateral outgoing branch, similar to a second one at *d*. At *f* is a transverse section of a corticated branch or root, with a vascular bundle in its centre, surrounded by two layers of a cortex, apparently like *b″* and *b′* of the branch B; *g′* and *g*, external cortical surfaces densely clothed with large curved multicellular hairs. Cabinet number, 1847. × 14	160
4	10	The clusters of hairs between the points *g* and *g* further enlarged. × 43	161
2	11	Transverse section of a branch of *Rachiopteris hirsuta*: *a*, the central vascular axis composed of reticulated tracheids; *c*, a zone of delicate parenchyma enclosed within *b*, which latter seems closely to resemble a bundle-sheath; *g*, *g′*, *g″*, *g‴*, four radiating appendages passing outwards from the supposed bundle-sheath, *b*, through the bark. These are probably roots. Cabinet number 1845. × 40	161
4	12	Obliquely tranverse section through another branch of *Rachiopteris hirsuta* passing through the central vascular bundle at *a*; *b*, the apparent bundle-sheath; *c*, the zone of the probable phloëm; *d*, *d*, *d′*, three	

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Plate.	Fig.		Pages on which references are made to the figures.
		radiating rootlets, *d″* being intersected transversely; *e*, cortical parenchyma. Cabinet number, 1846. × 17	161
4	13	A transverse section of a free rootlet, with a structure identical with that of fig. 12, *d″*; *a*, a central vascular axis; *b*, apparent bundle-sheath, enclosing the phloëm, *c*, with the two cortical layers, *d′* and *e′*. Cabinet number, 1844. × 38	161
4	14	A section of a second free rootlet like fig. 13: *b*, apparent vascular bundle-sheath, enclosing the apparent phloëm, *c*, and again invested by the two cortical layers, *d* and *e*. The vascular bundles are either those of a diarch root or they are concentric bundles like those of Ferns, the development of which began in the two foci of an ellipse of procambium. Cabinet number, 1844. × 38	161
1	15	Section of another and apparently younger rootlet than 13 and 14, in which the cortical cells, *e*, are arranged in the cycloidal order common amongst these young rootlets: *a*, vascular bundle; *b*, bundle-sheath or pericambium; *c*, zone occupied by phloëm. × 96	161
4	16	Longitudinal section through the root of *Rhizonium verticillatum*: *a*, a central vascular bundle; *a′*, secondary vascular bundles going obliquely downwards to the several rootlets of each verticil *c*, *c*; *b′*, delicate parenchyma surrounding the vascular bundle; *b*, outer cortical parenchyma. Cabinet number, 1909. × 15	162
4	17	Transverse section of a root like fig. 16: *a*, a central vascular bundle the transverse section of which is triangular; *b′*, inner cortical cells arranged in cycloidal order; *b*, external cortex; *c*, *c*, *c*, *c*, *c*, longitudinal sections of the bases of five rootlets of one of the rootlet verticils. Cabinet number, 1907. × 65	162

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Plate.	Fig.		Pages on which references are made to the figures.
3	18	Central portion of fig. 17 further enlarged; *a*, fibro-vascular bundle; *b*, phloëm; *c*, inner cortex. × 400	162
3	19	Central vascular axis of another transverse section like 17, enlarged equally to fig. 18: *a*, vascular bundle; *b*, phloëm; *c*, cortical parenchyma. Cabinet number, 1234. × 400	162
3	20	Transverse section of a triarch root, from Halifax: *a*, triarch vascular bundle; *b*, phloëm or procambium; *c*, position of the bundle-sheath; *d*, cortex. Cabinet number, 1234. × 44	162
3	21	Central portion of fig. 20, further enlarged: *a*, vascular bundle; *b*, phloëm; *d*, cortical cells. × 175 . .	162
3	22	Obliquely transverse section of a root with a lacunar cortex, from Halifax: *a*, the vasculo-medullary axis with some vessels imbedded in procambial or phloëm tissue; *b*, inner cortex with large, radiating, irregular lacunæ; *c*, outer cortex. Cabinet number, 1350. × 45	163
3	23	Transverse section of another lacunar root: *a*, medullary cells; *b*, cylinder of tracheids; *c*, cycloidally-arranged endodermal cells; *d*, numerous thin radiating cellular laminæ, extending, when not ruptured, from the endoderm, *c*, to the external cortical parenchyma, *f*, and including numerous large lacunæ, *e*. Cabinet number, 1892. × 7	163

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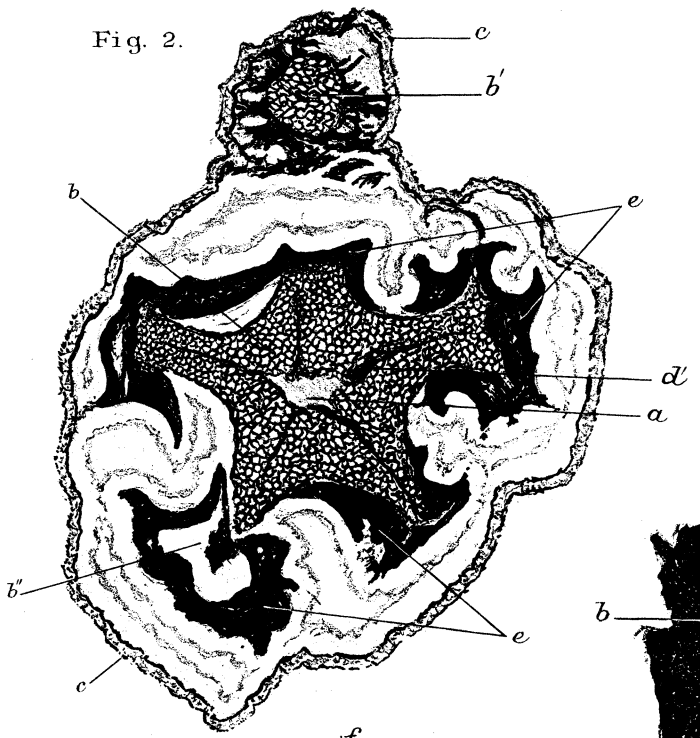
Fig. 2.



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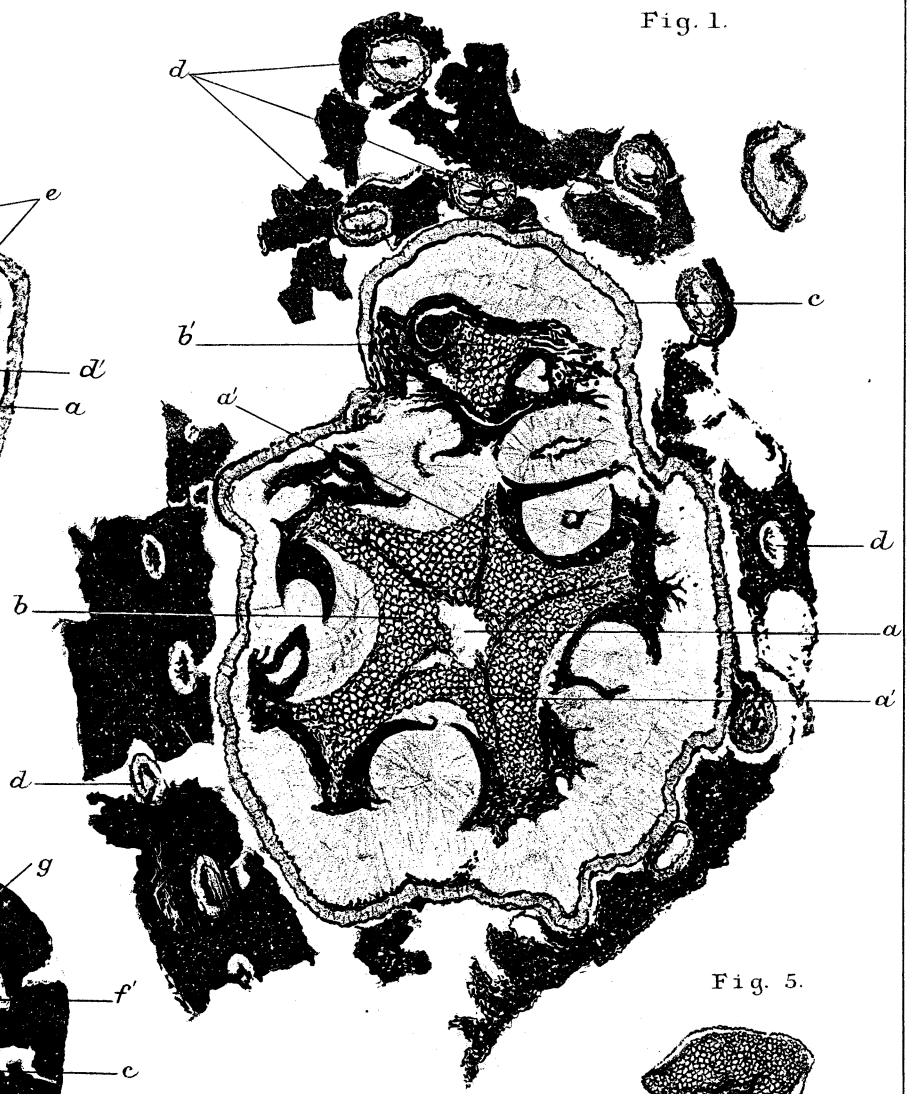

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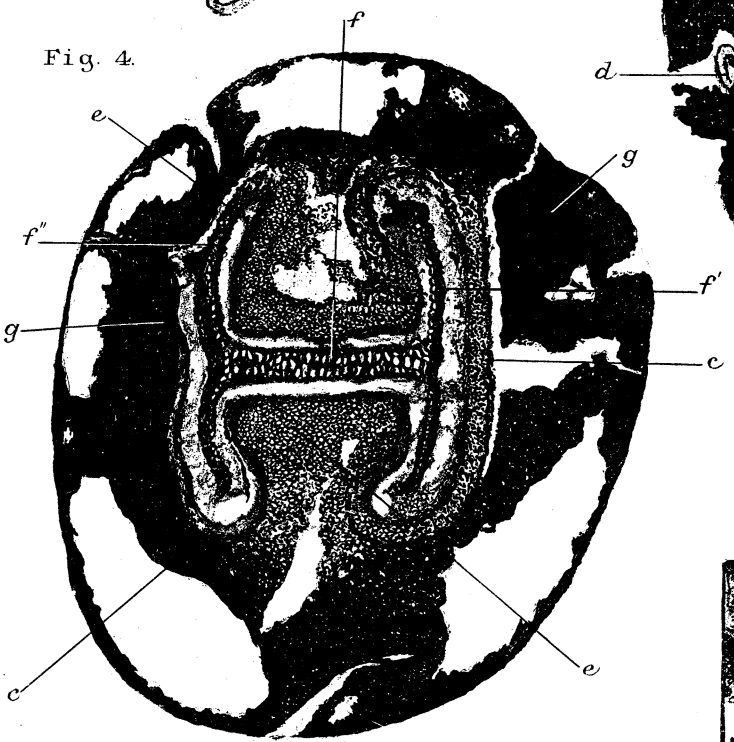

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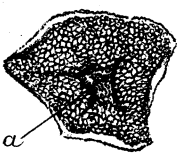

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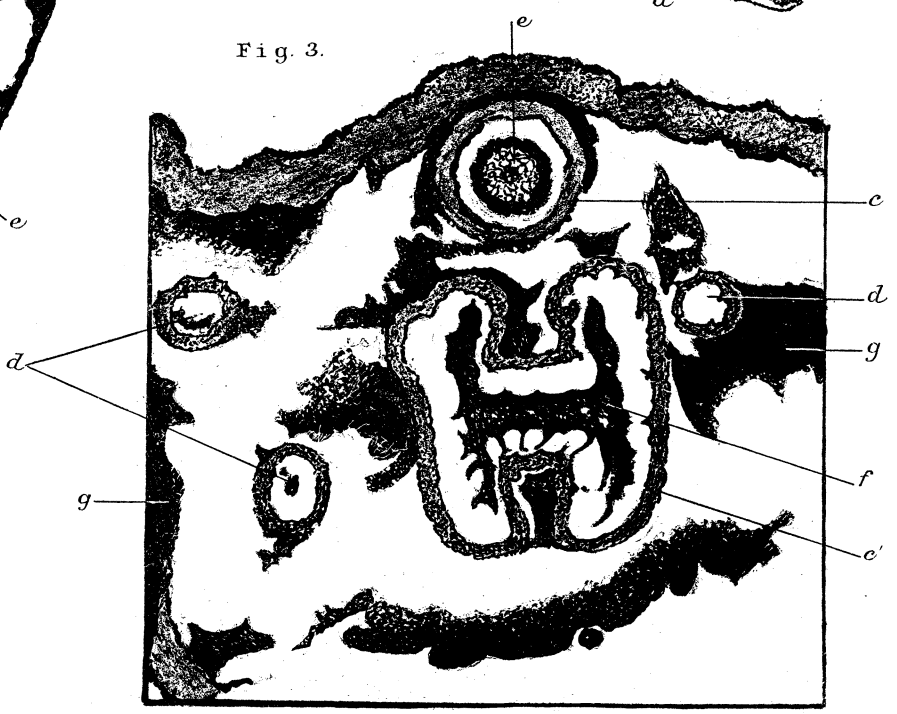

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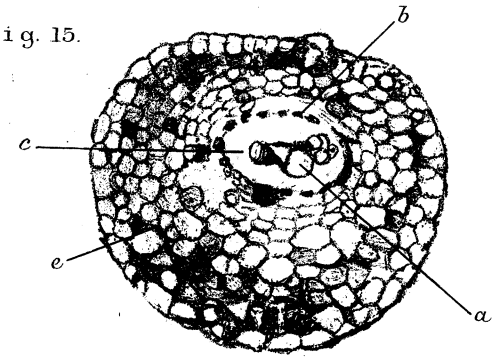

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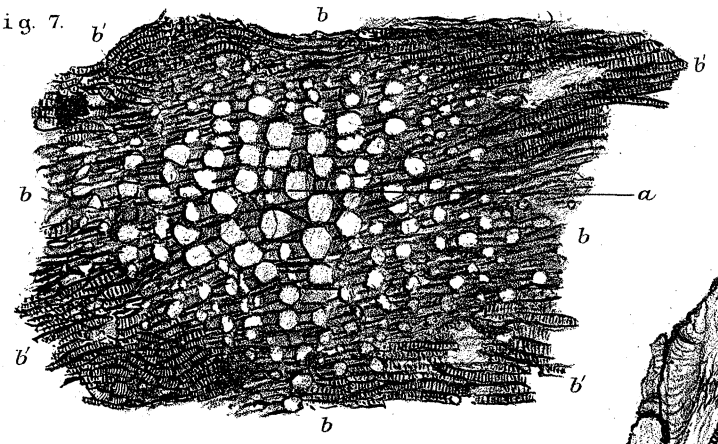

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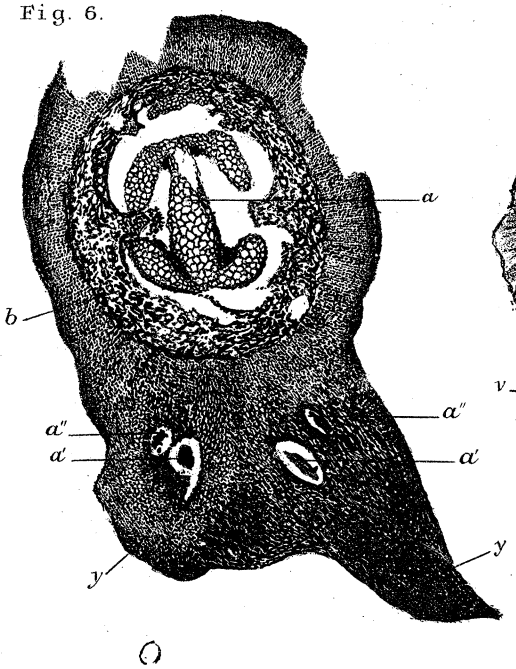

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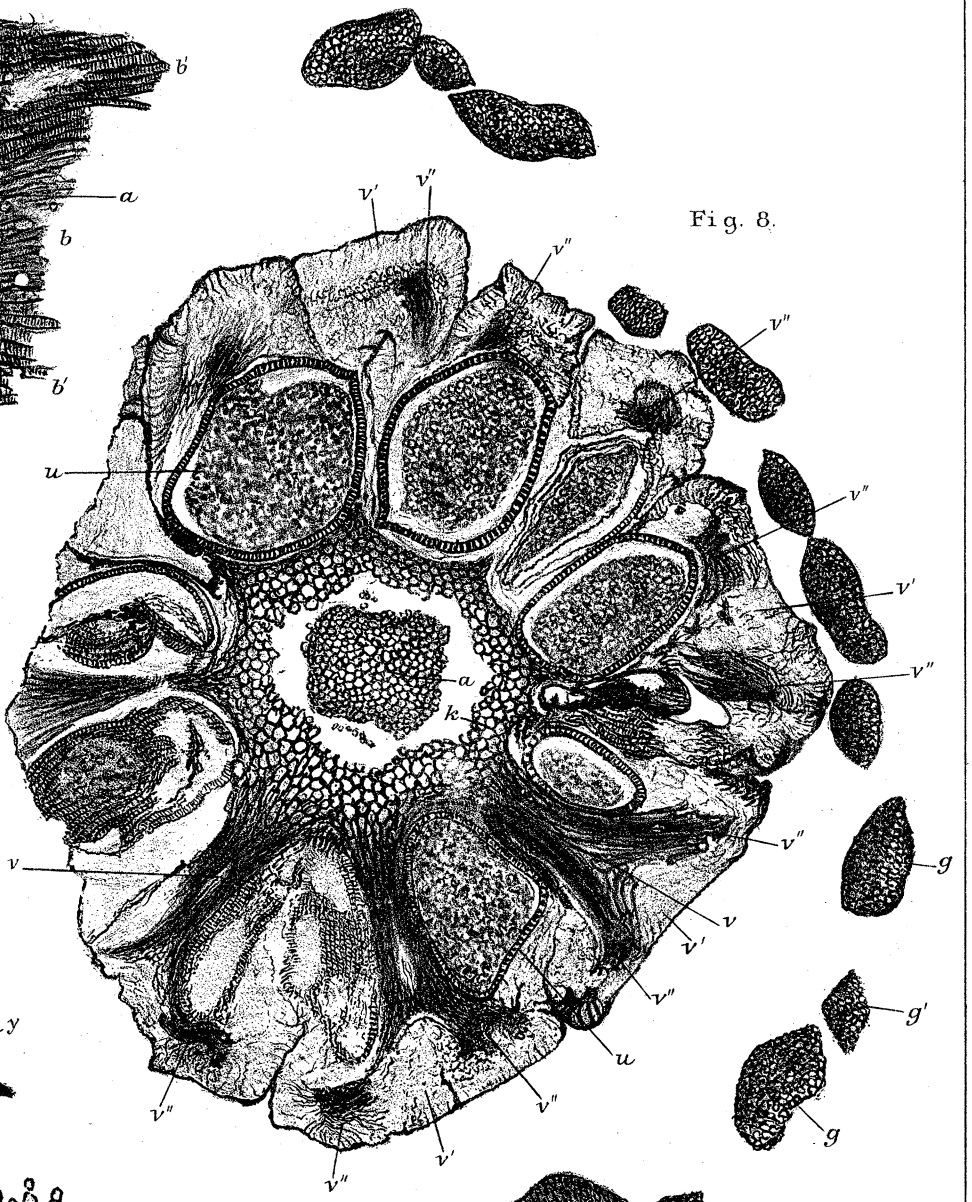


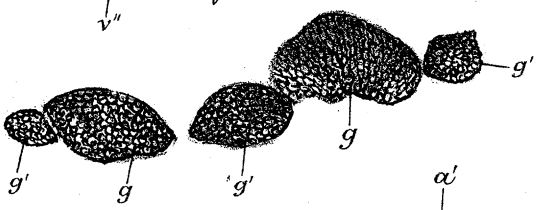
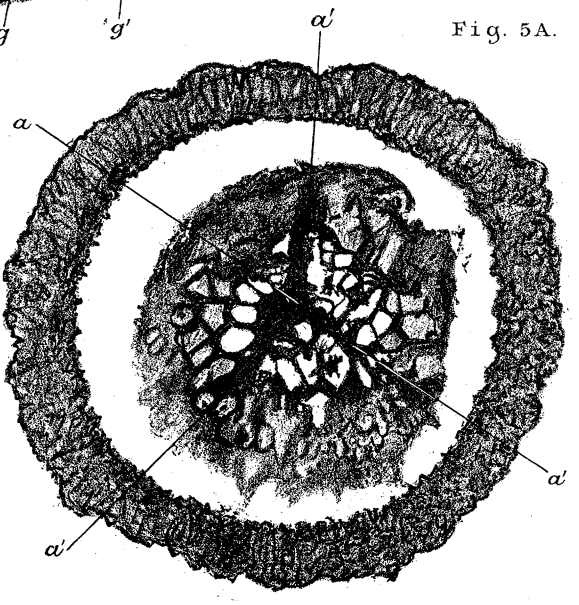


Fig. 5A.



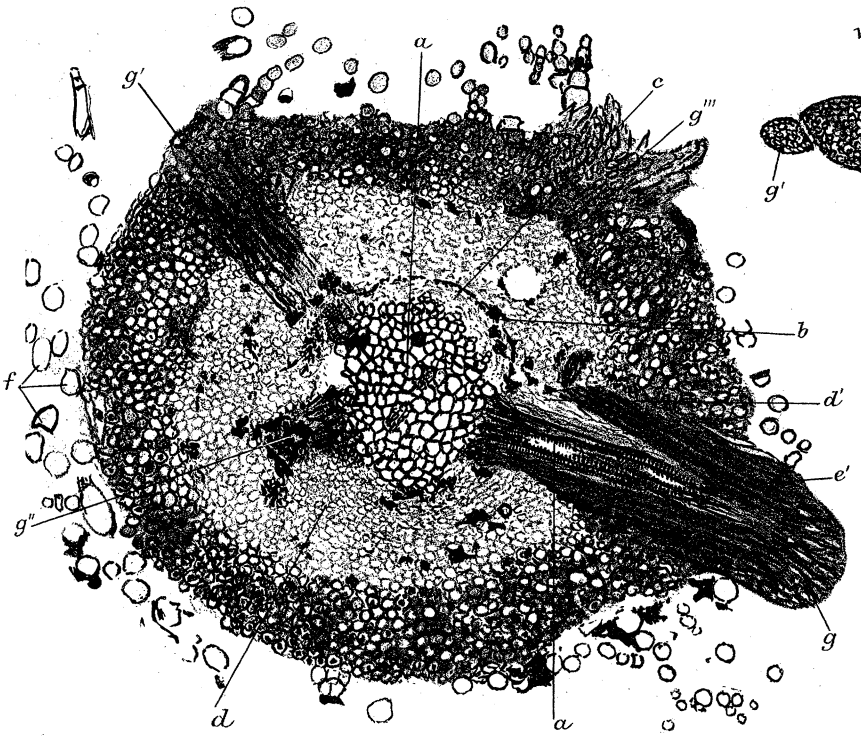


Fig. 11.

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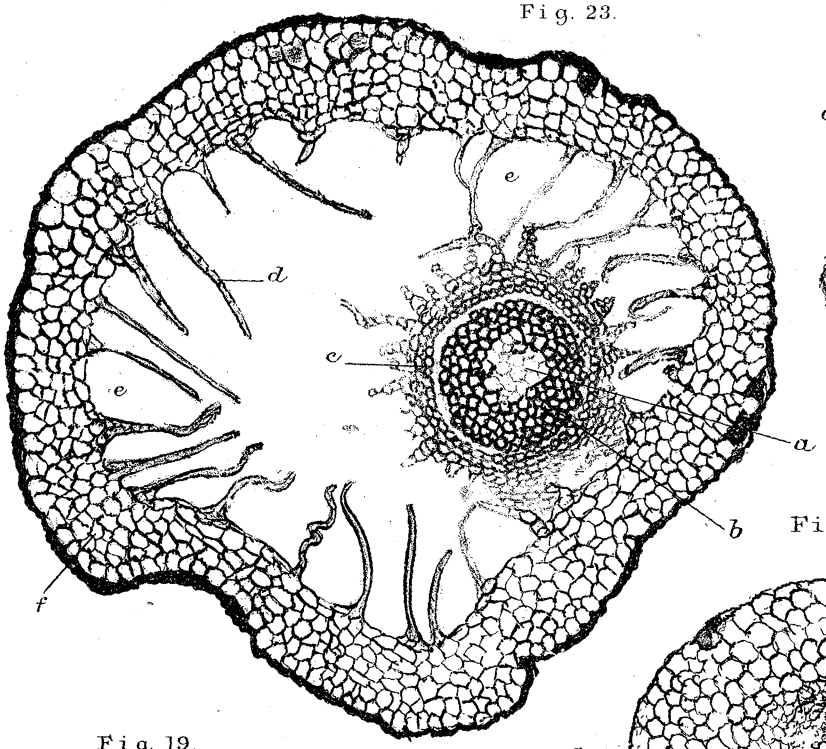

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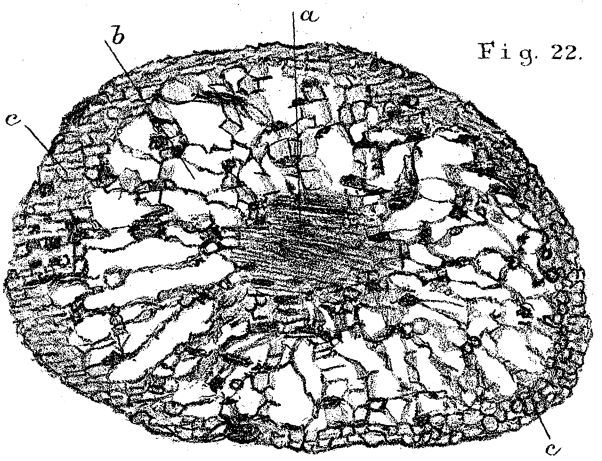

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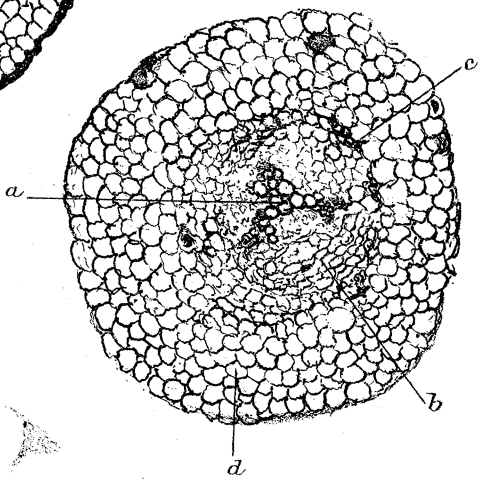

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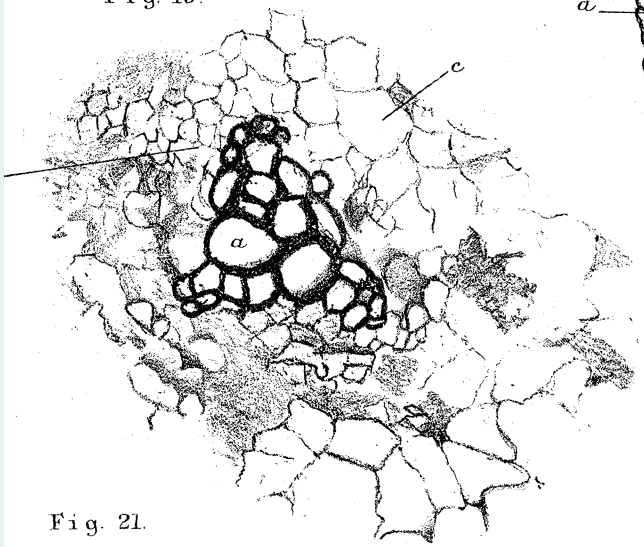


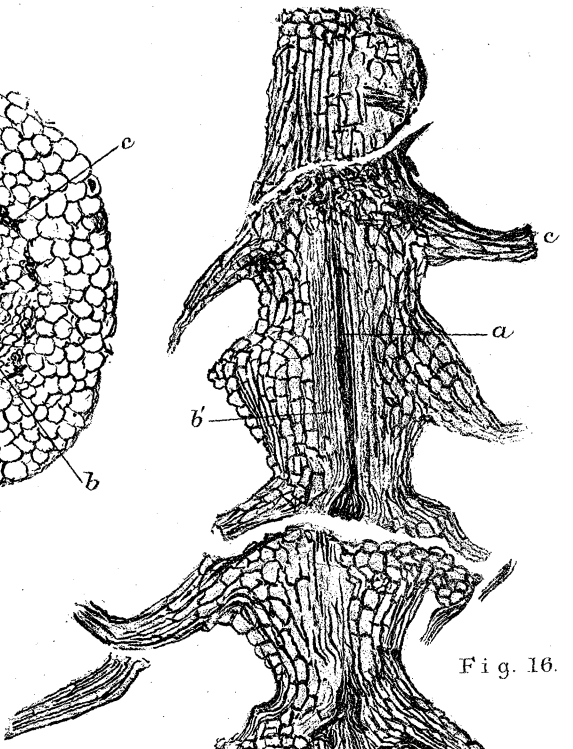
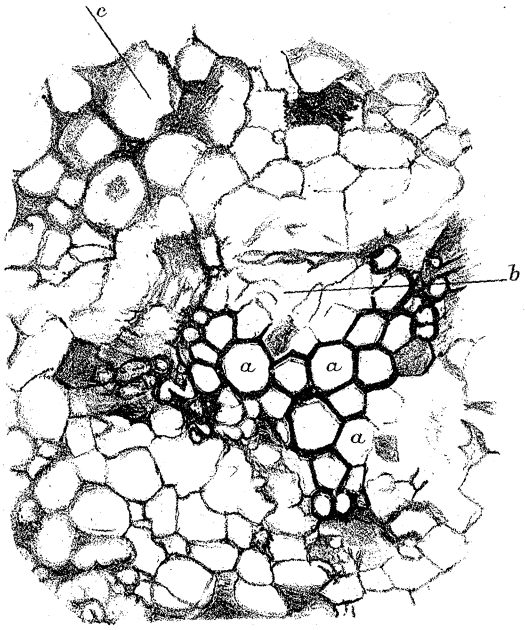


Fig. 16.

Fig. 21.



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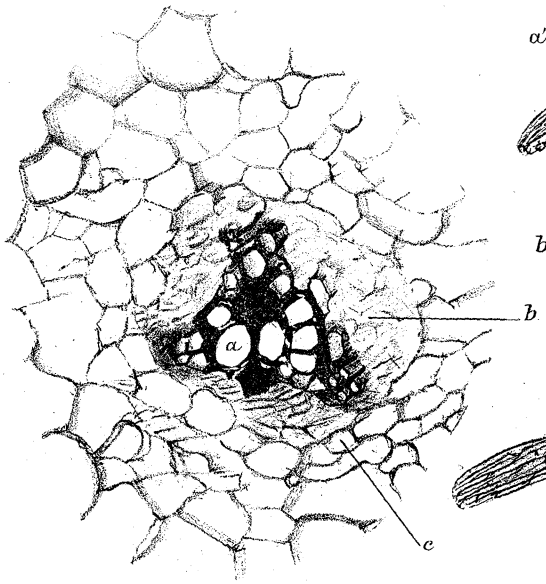

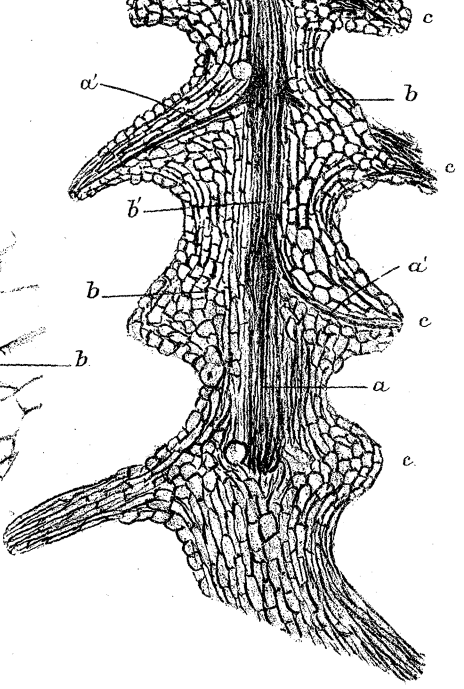

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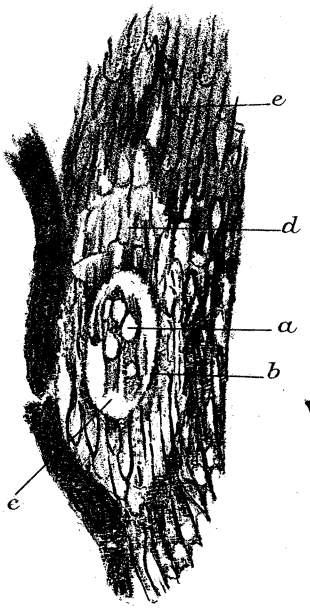

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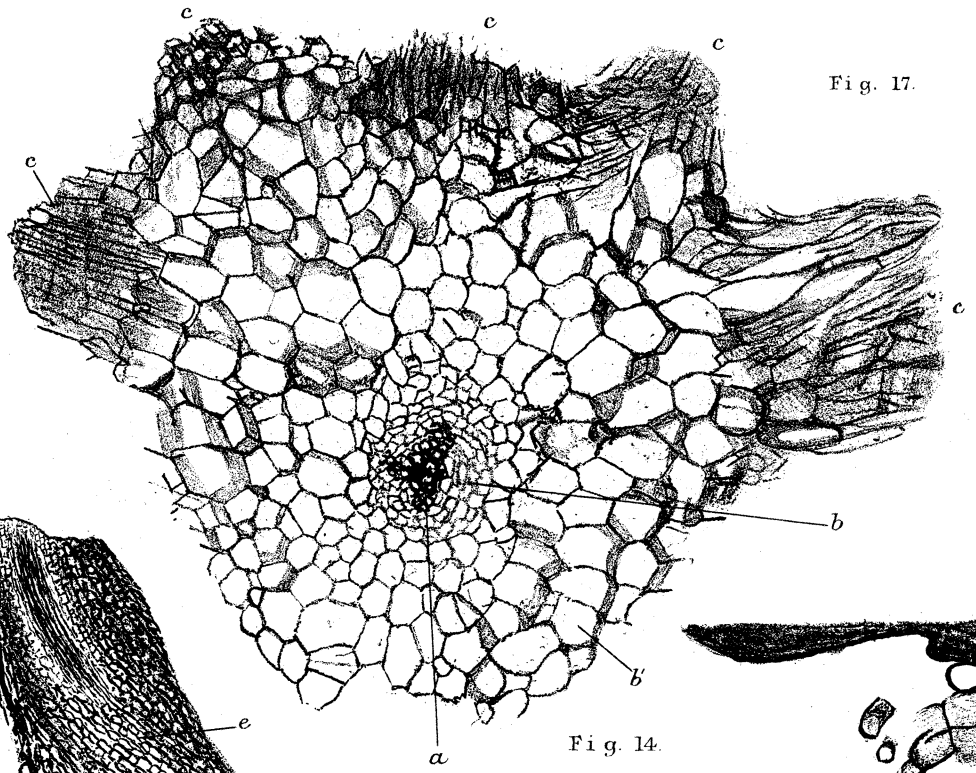

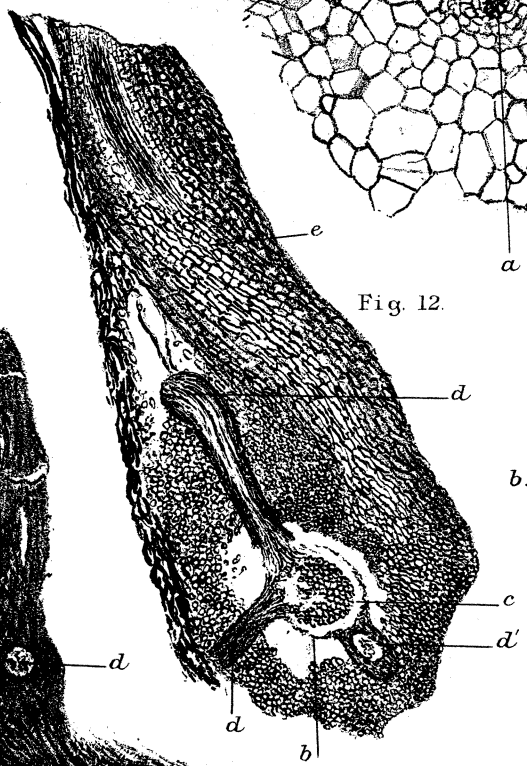

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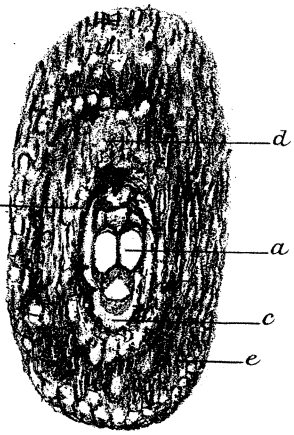

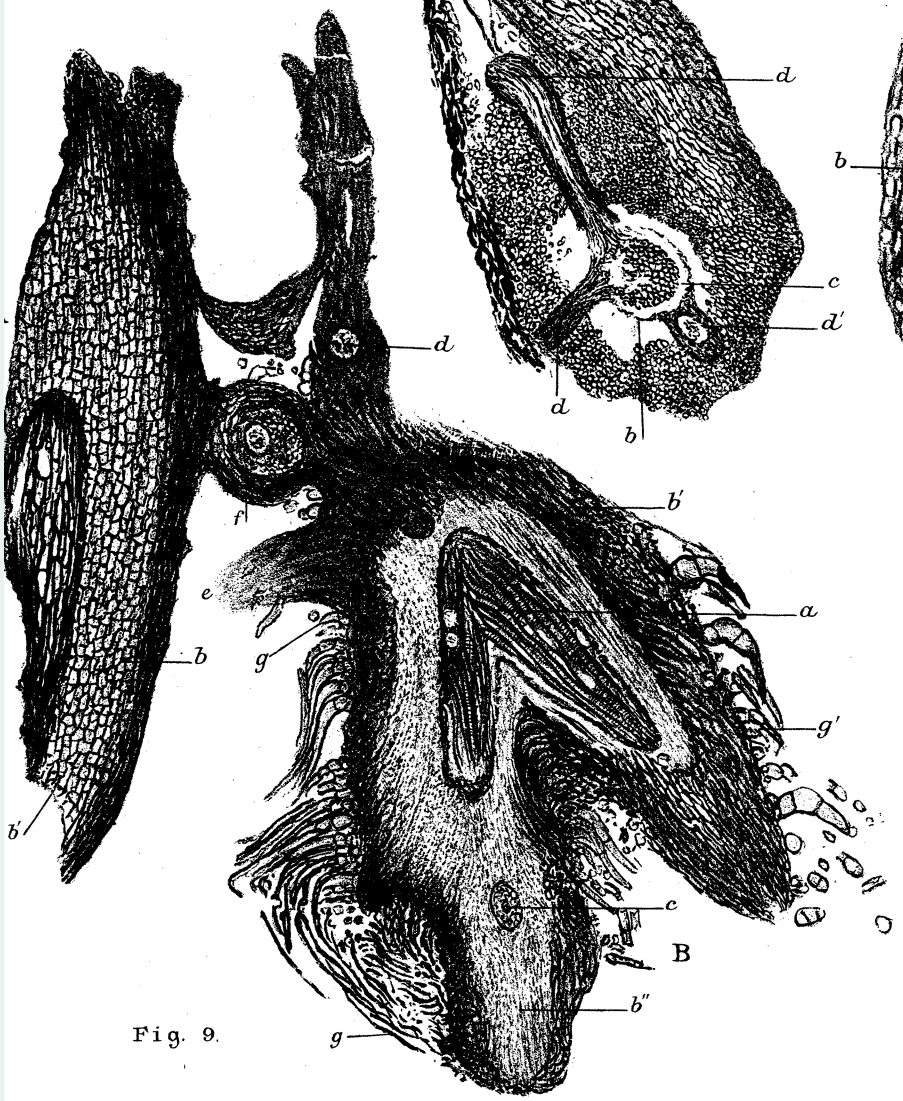

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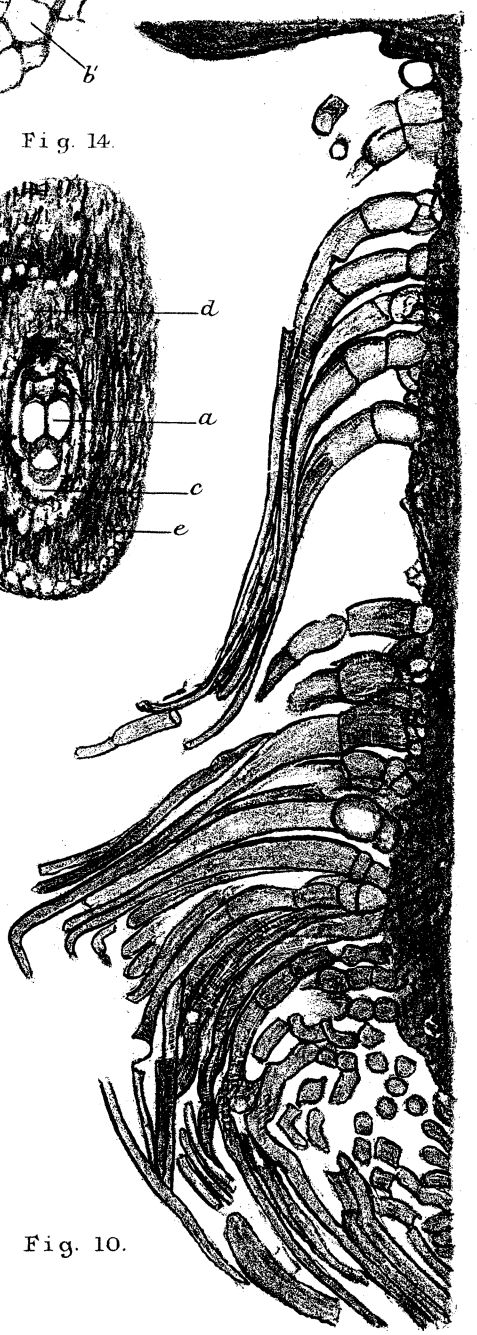

Fig. 10.

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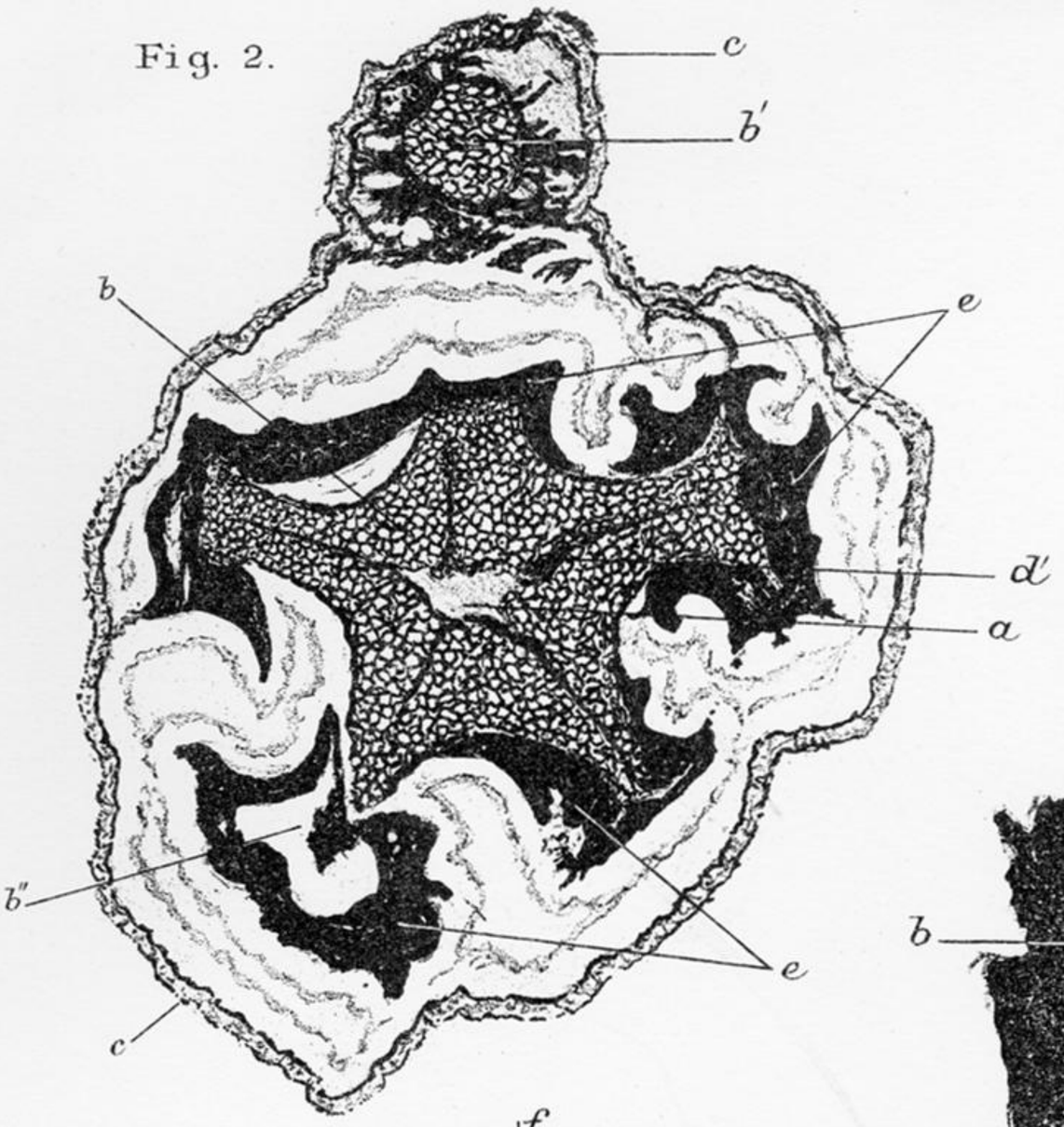
Fig. 2.



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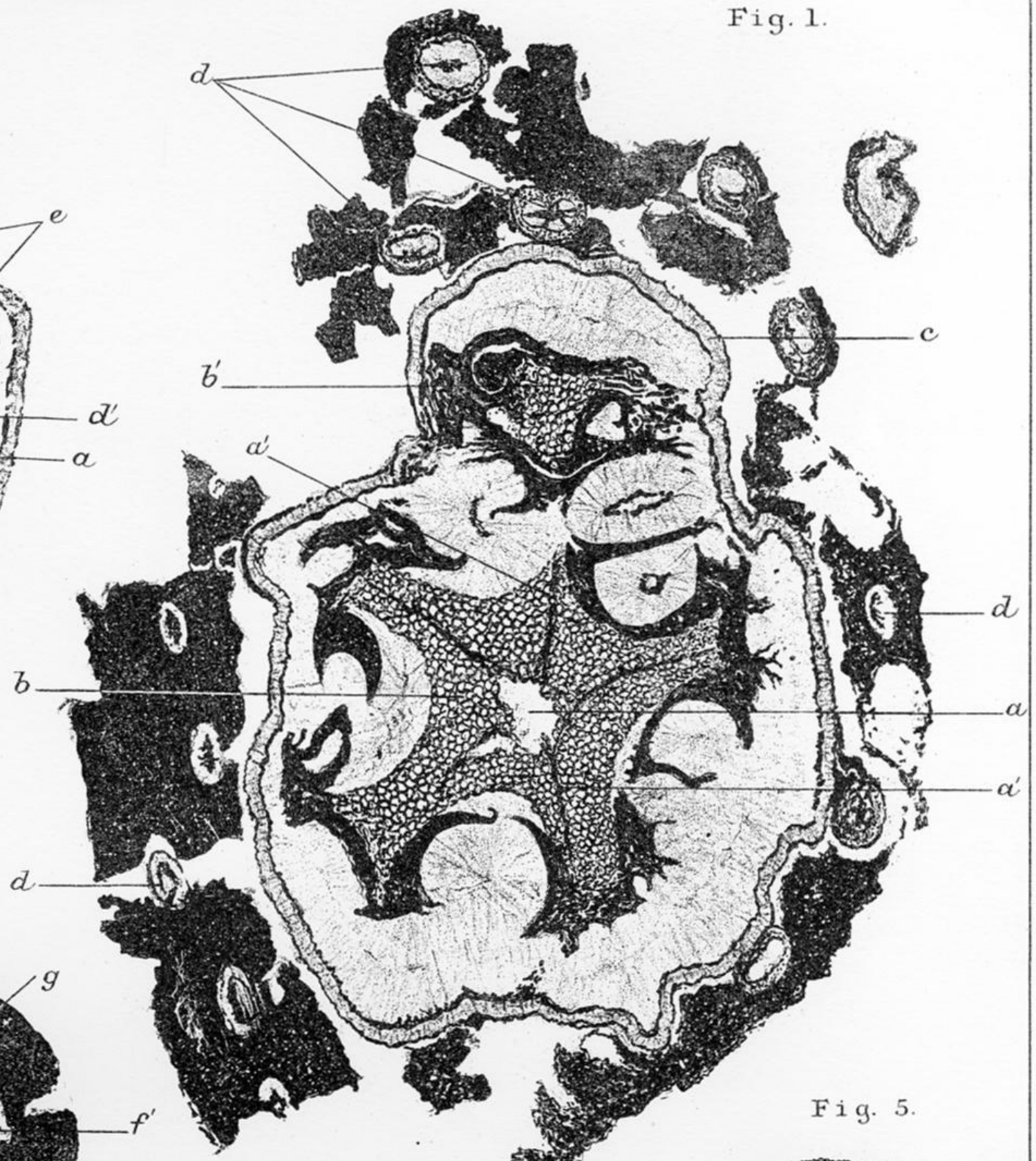

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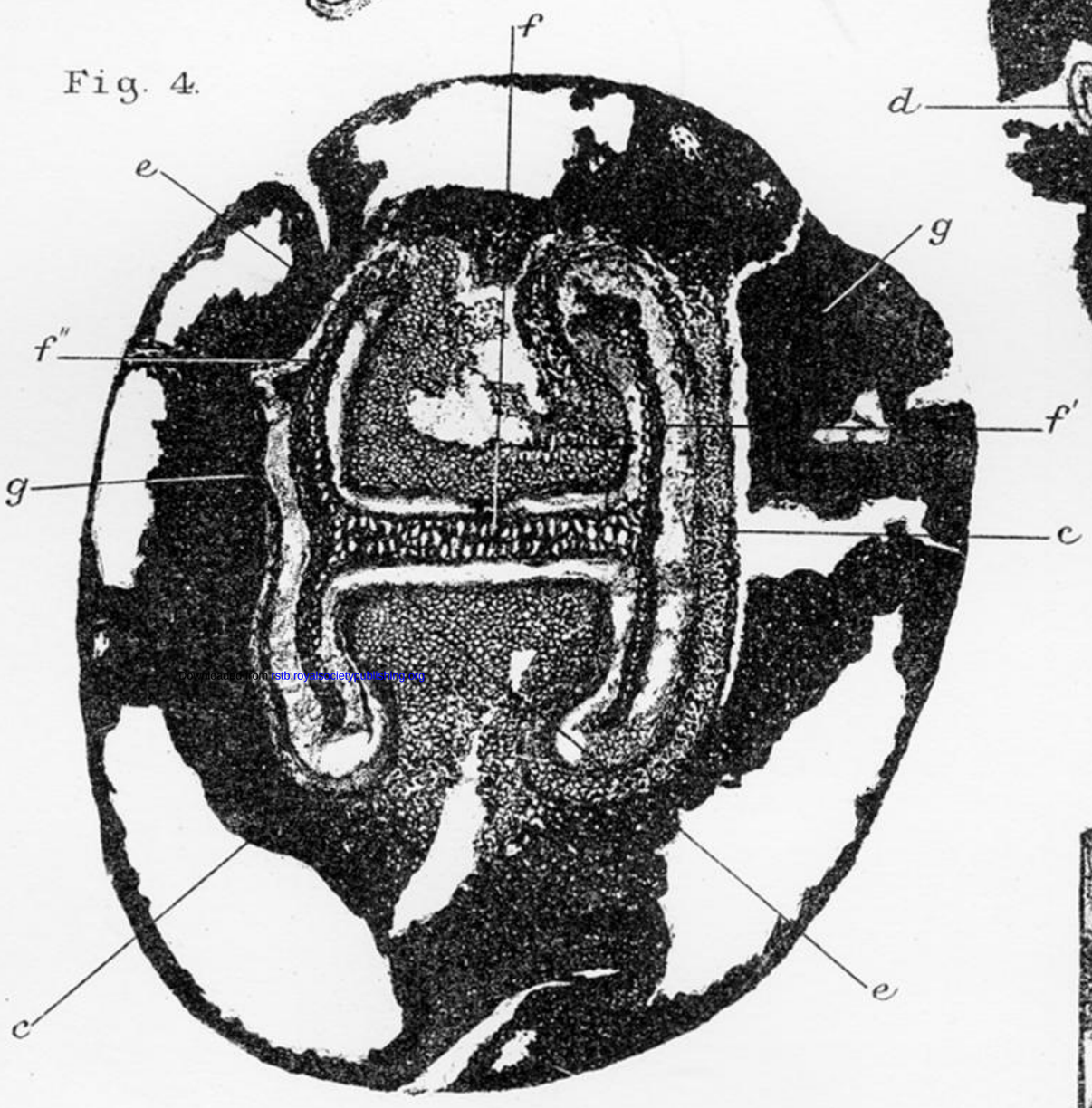
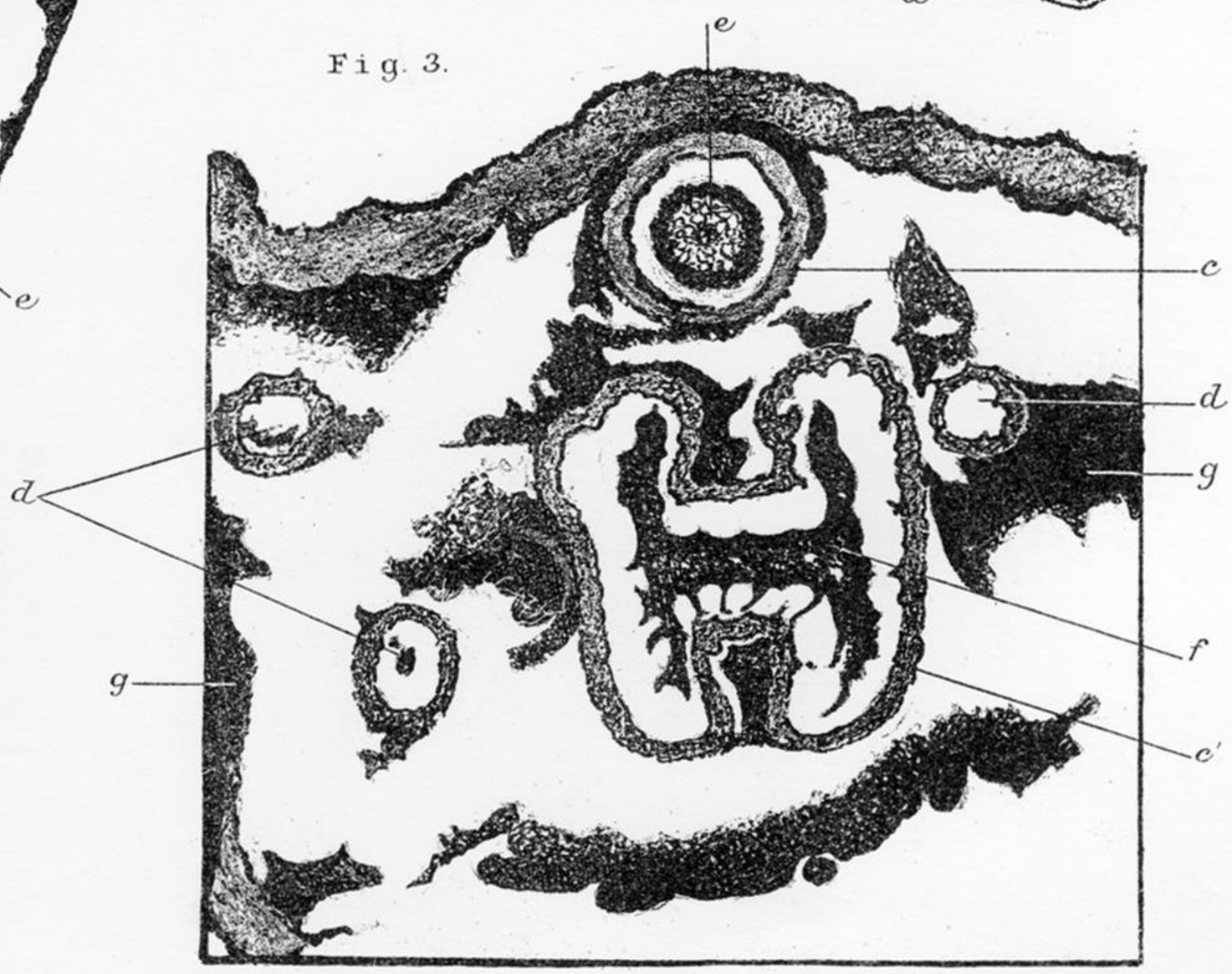


Fig. 5.

Fig. 3.



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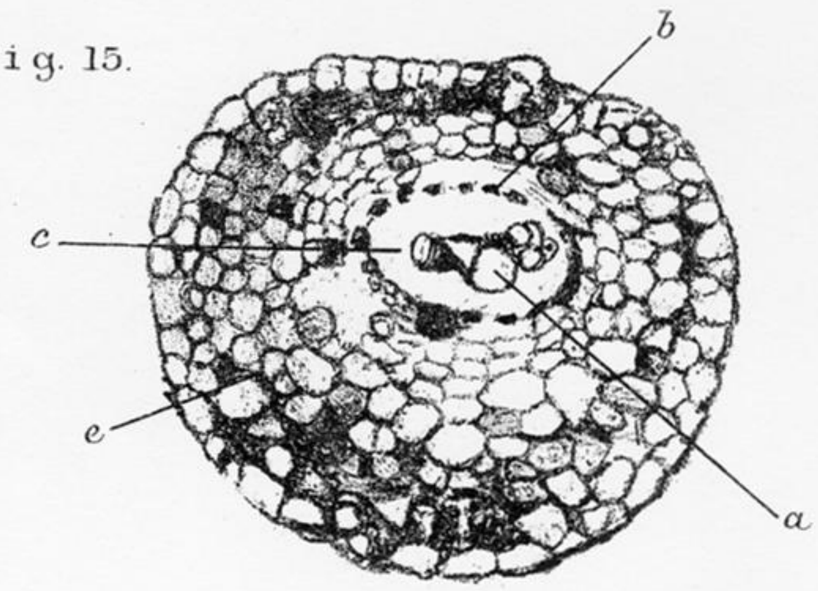

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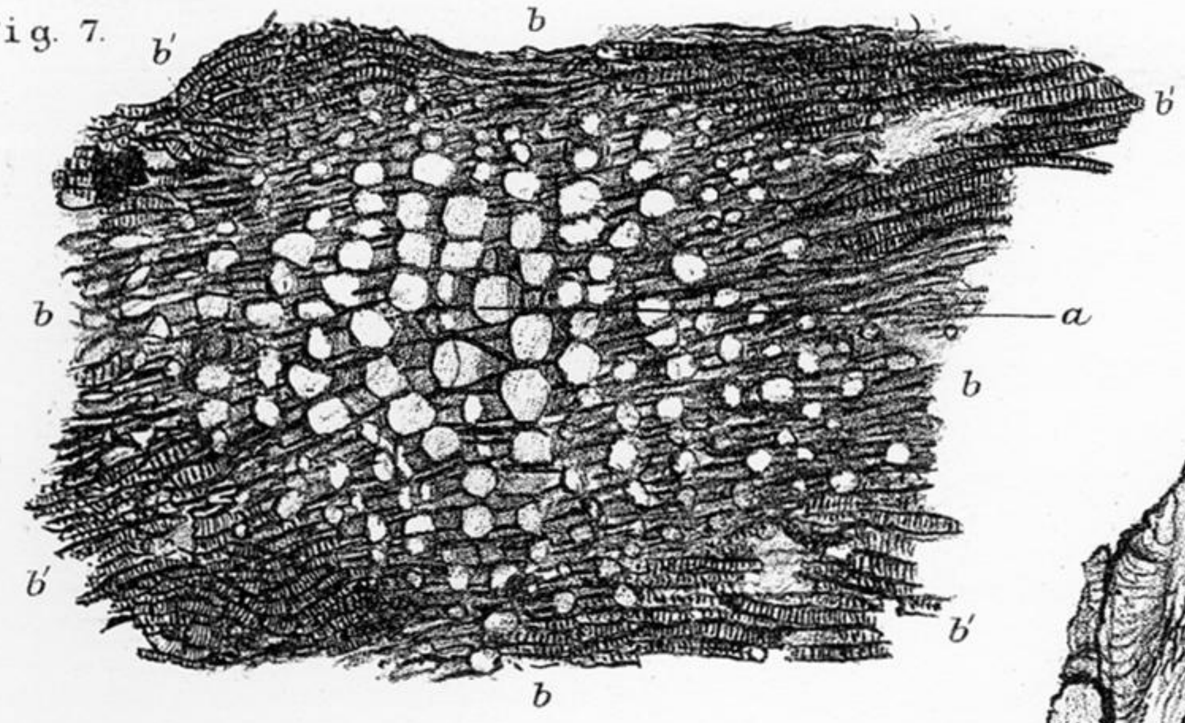
Fig. 7.



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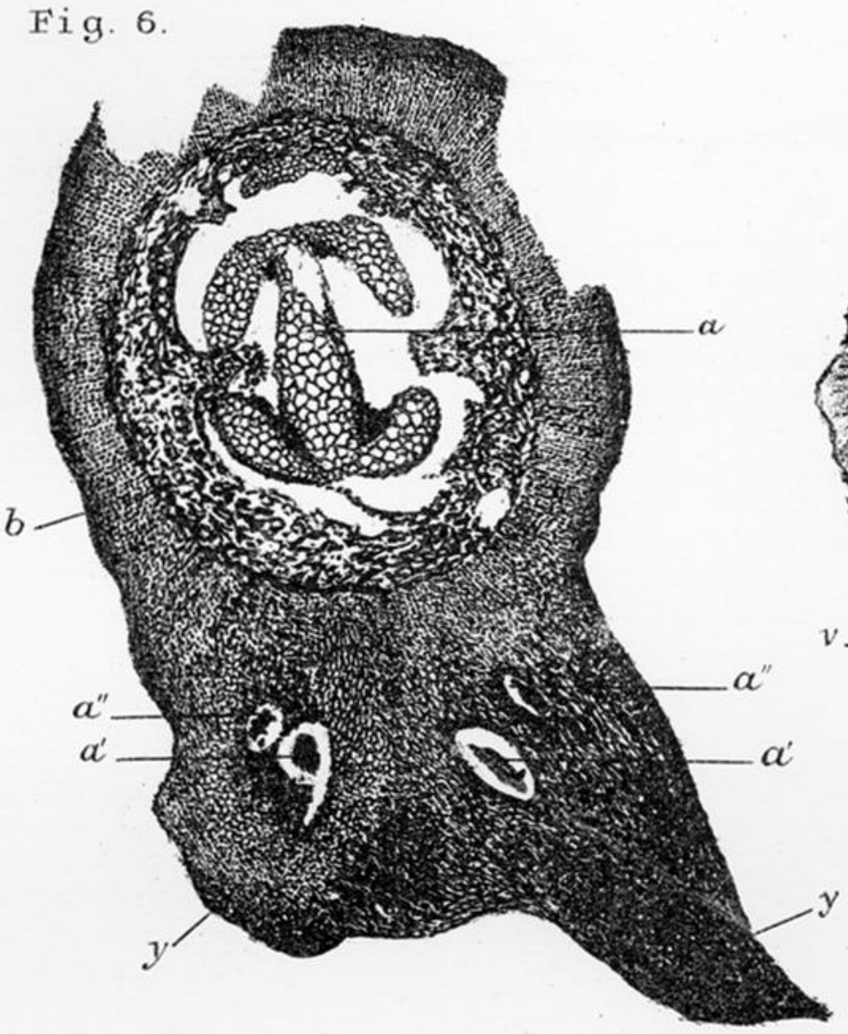

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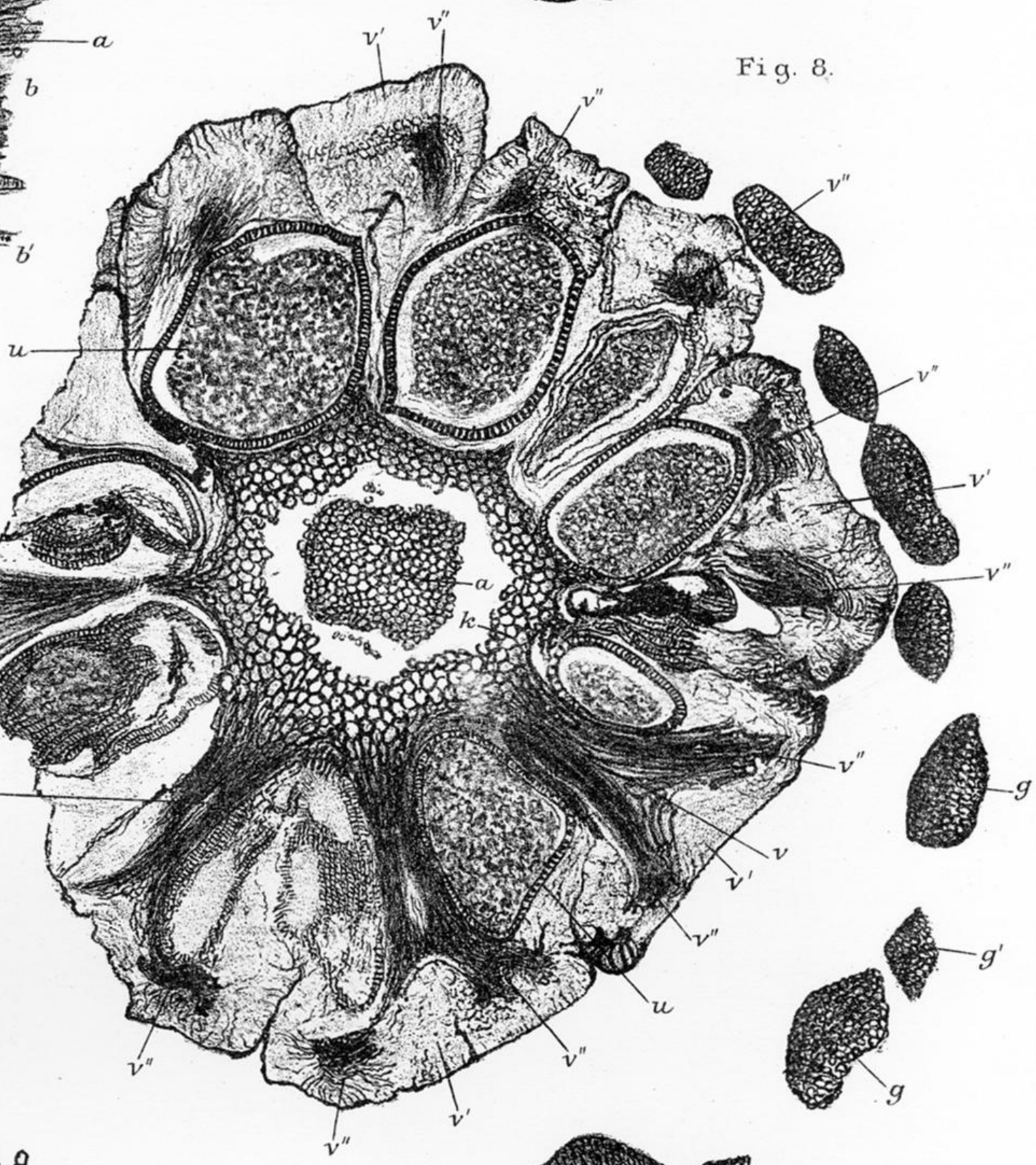

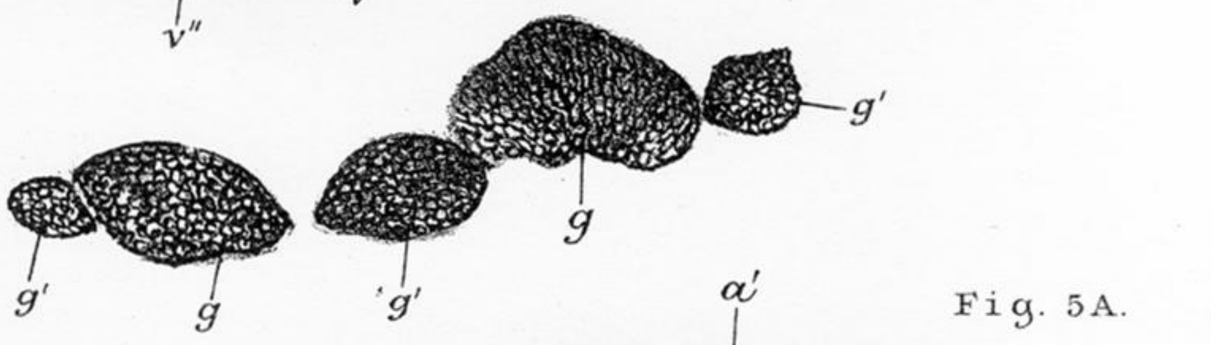

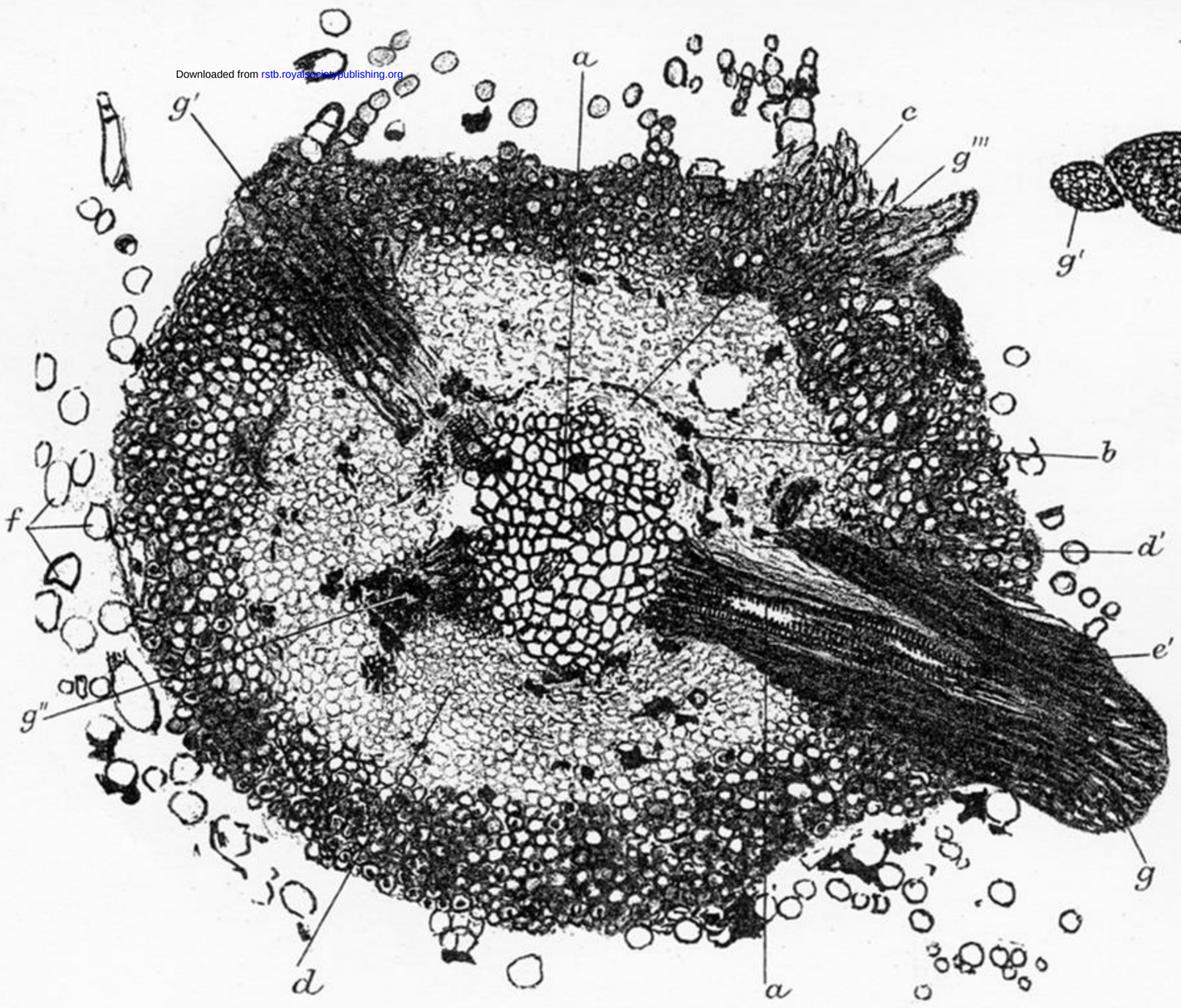

Fig. 11.

Fig. 5A.

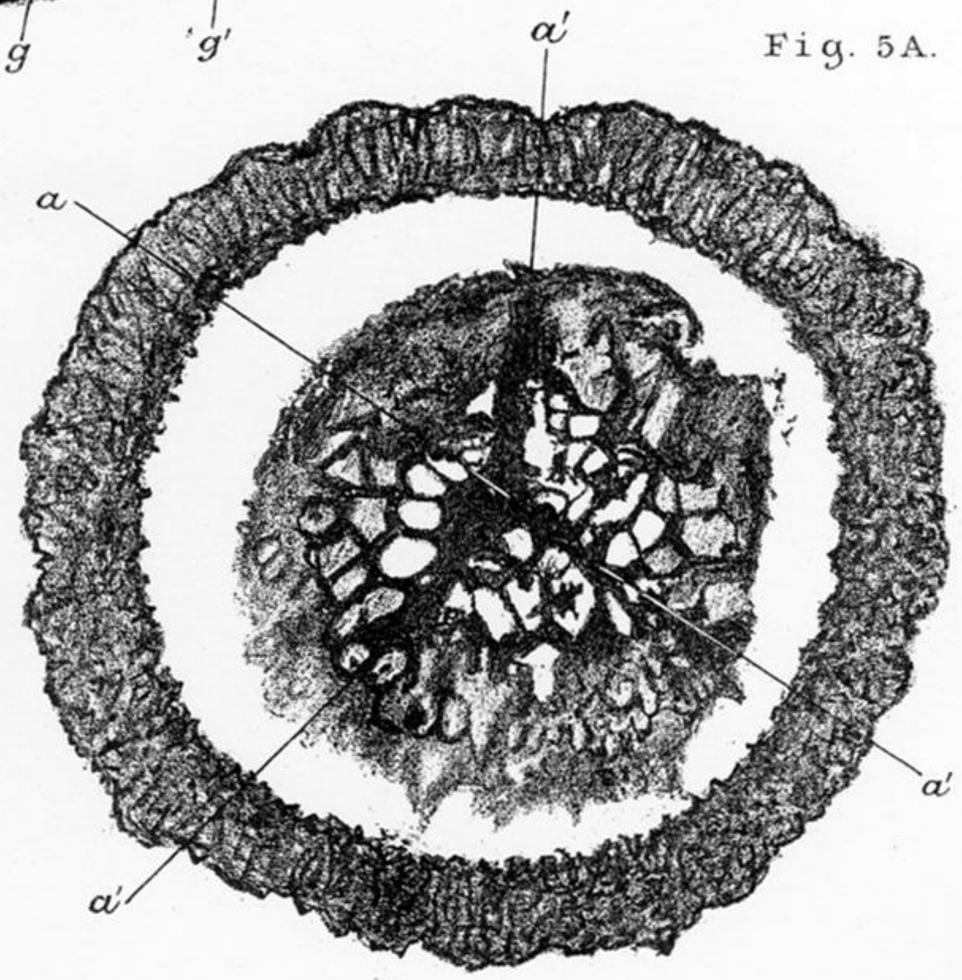

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Fig. 23.

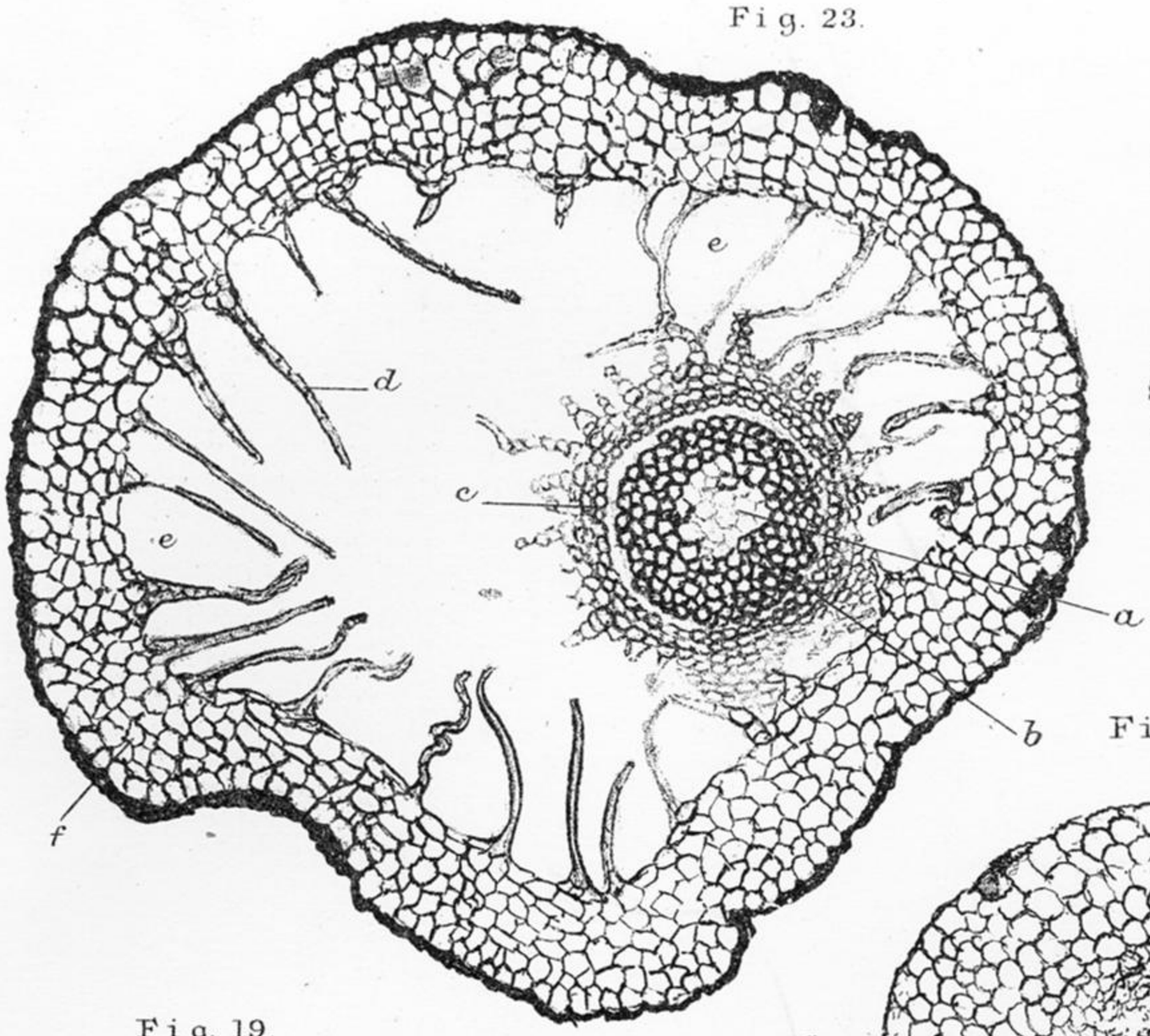
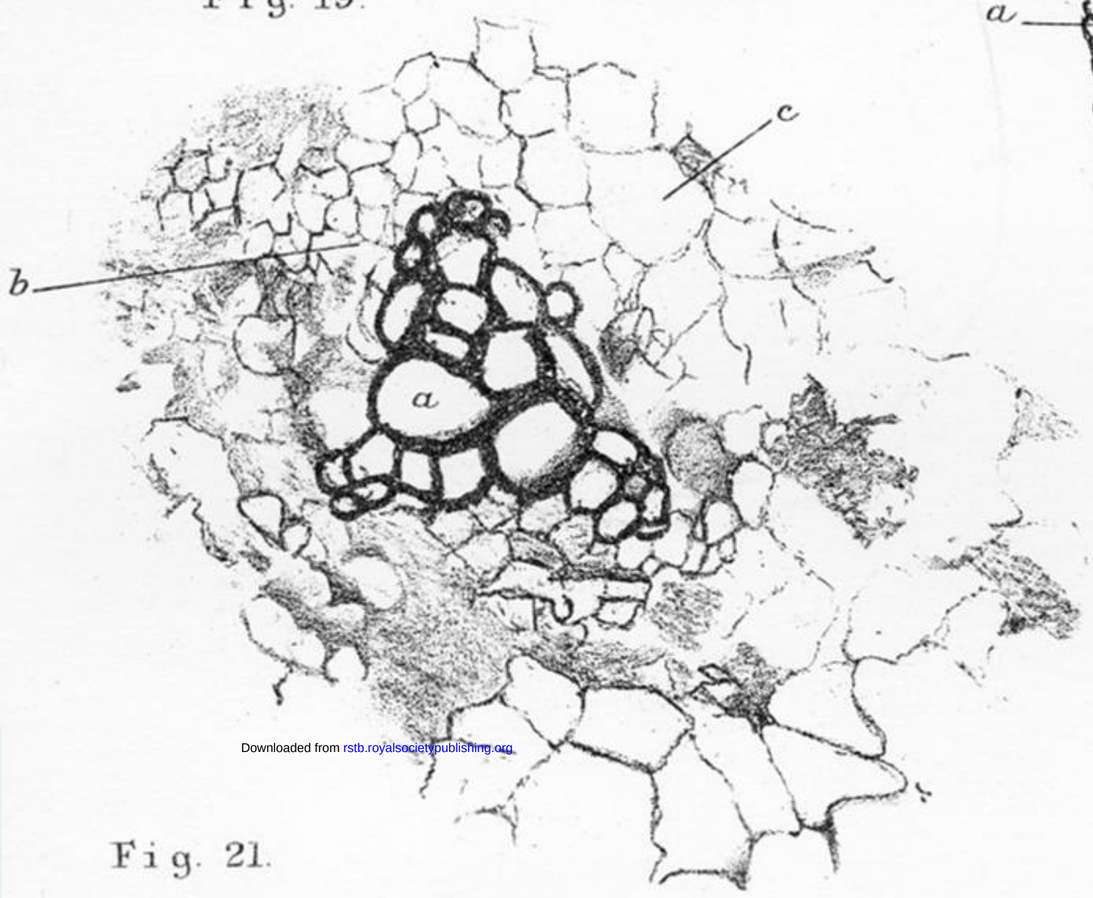


Fig. 19.



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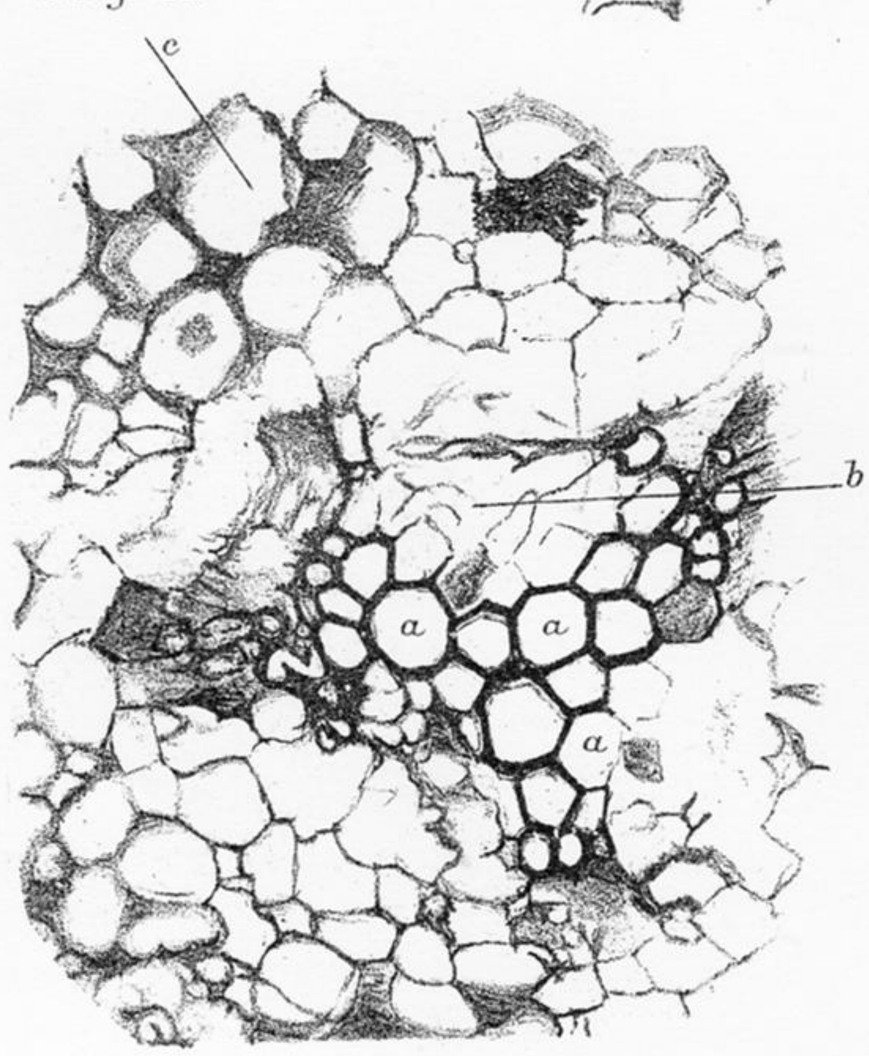

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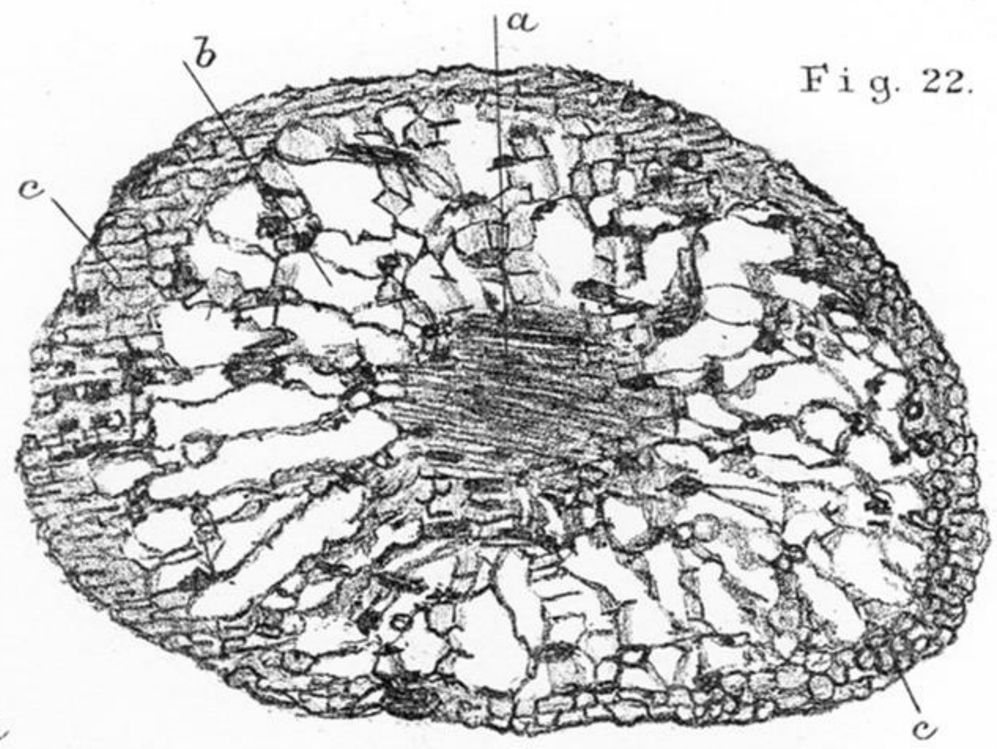

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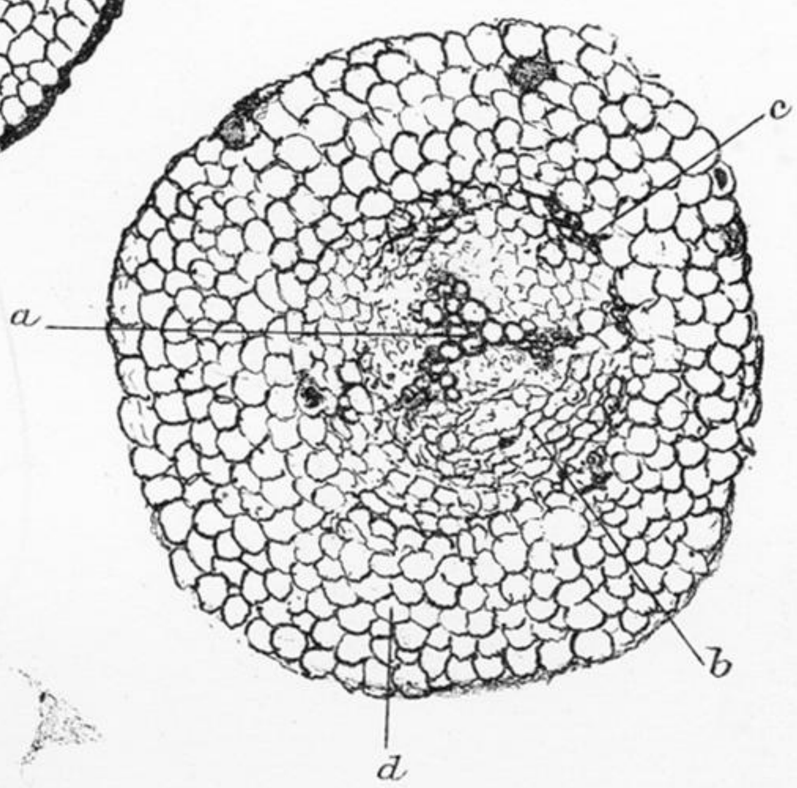

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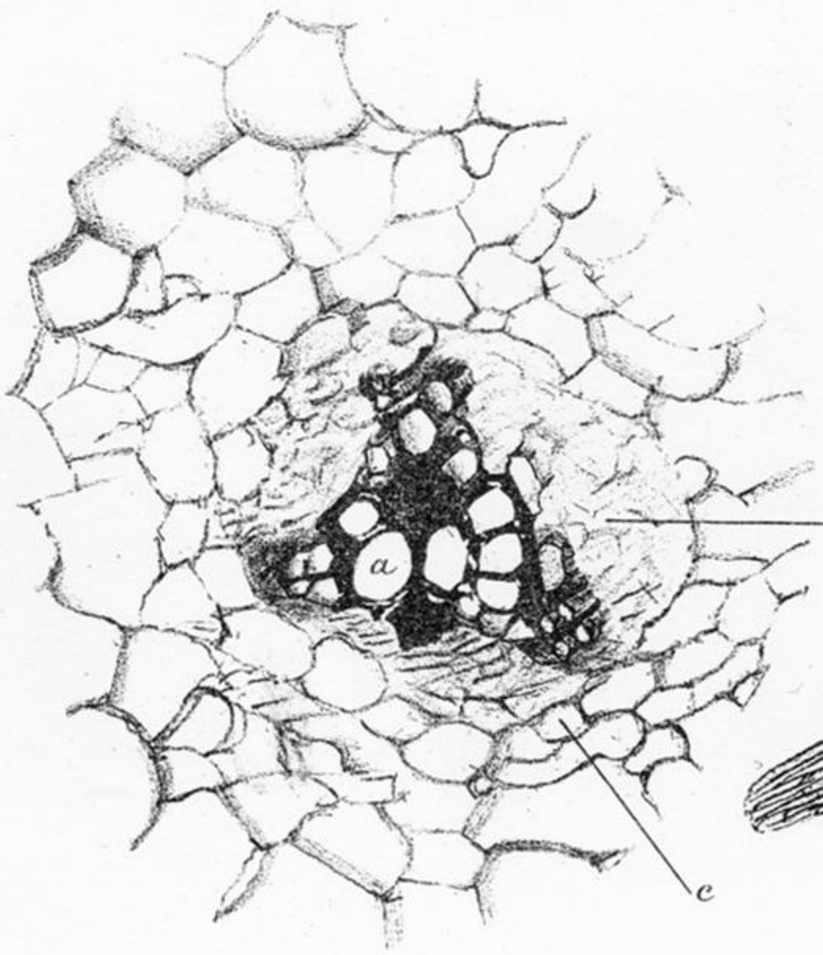

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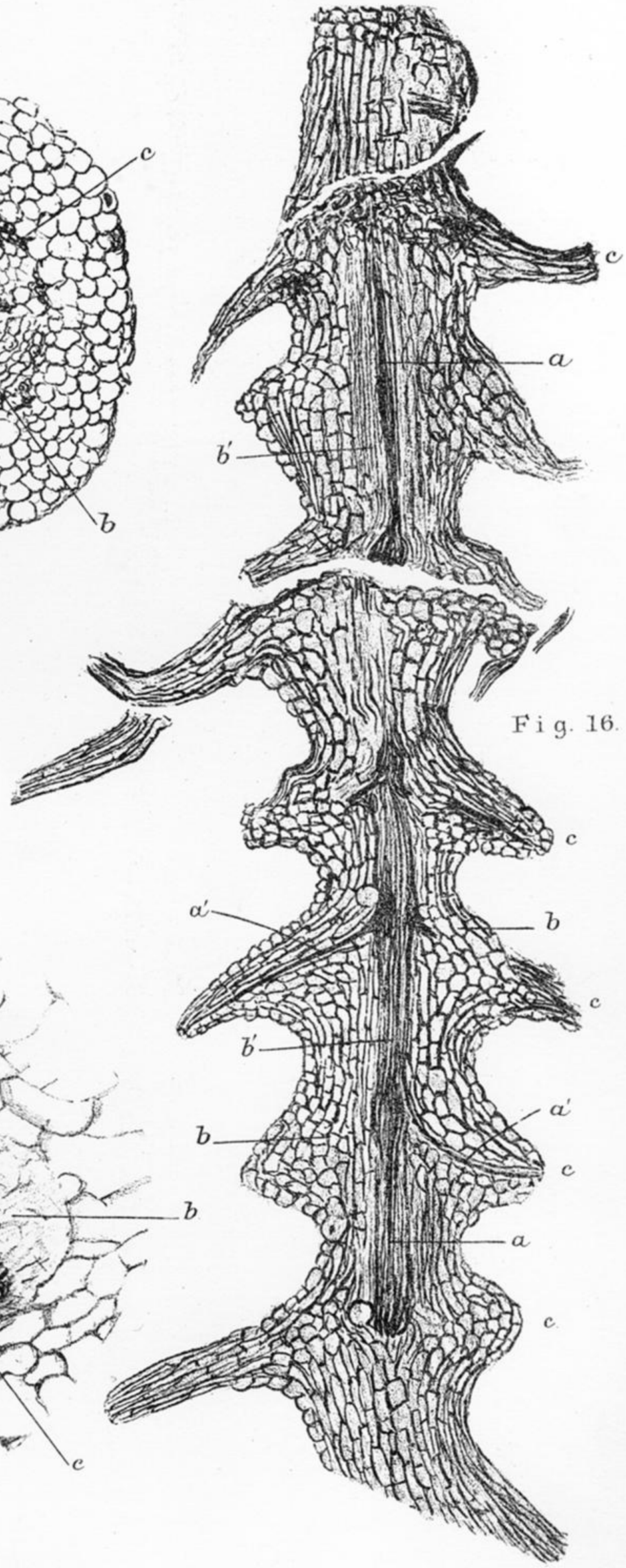

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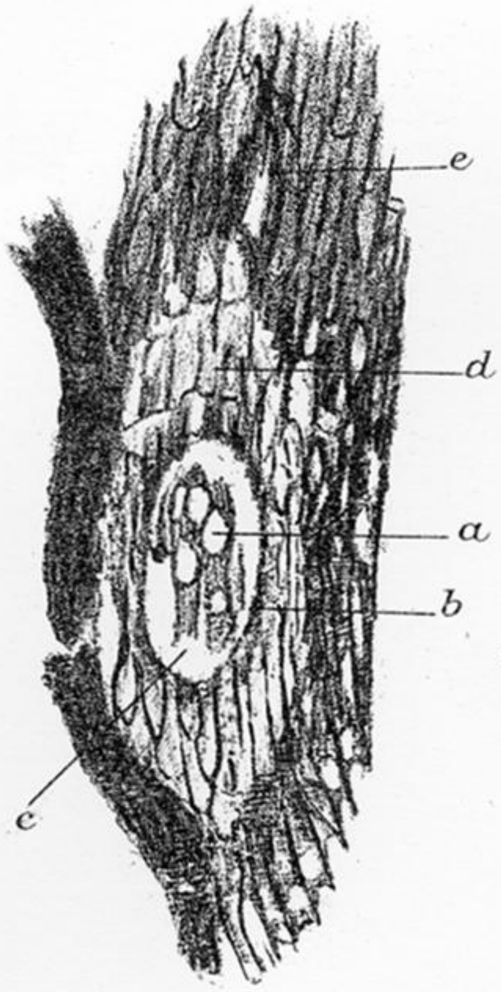
Fig. 13.



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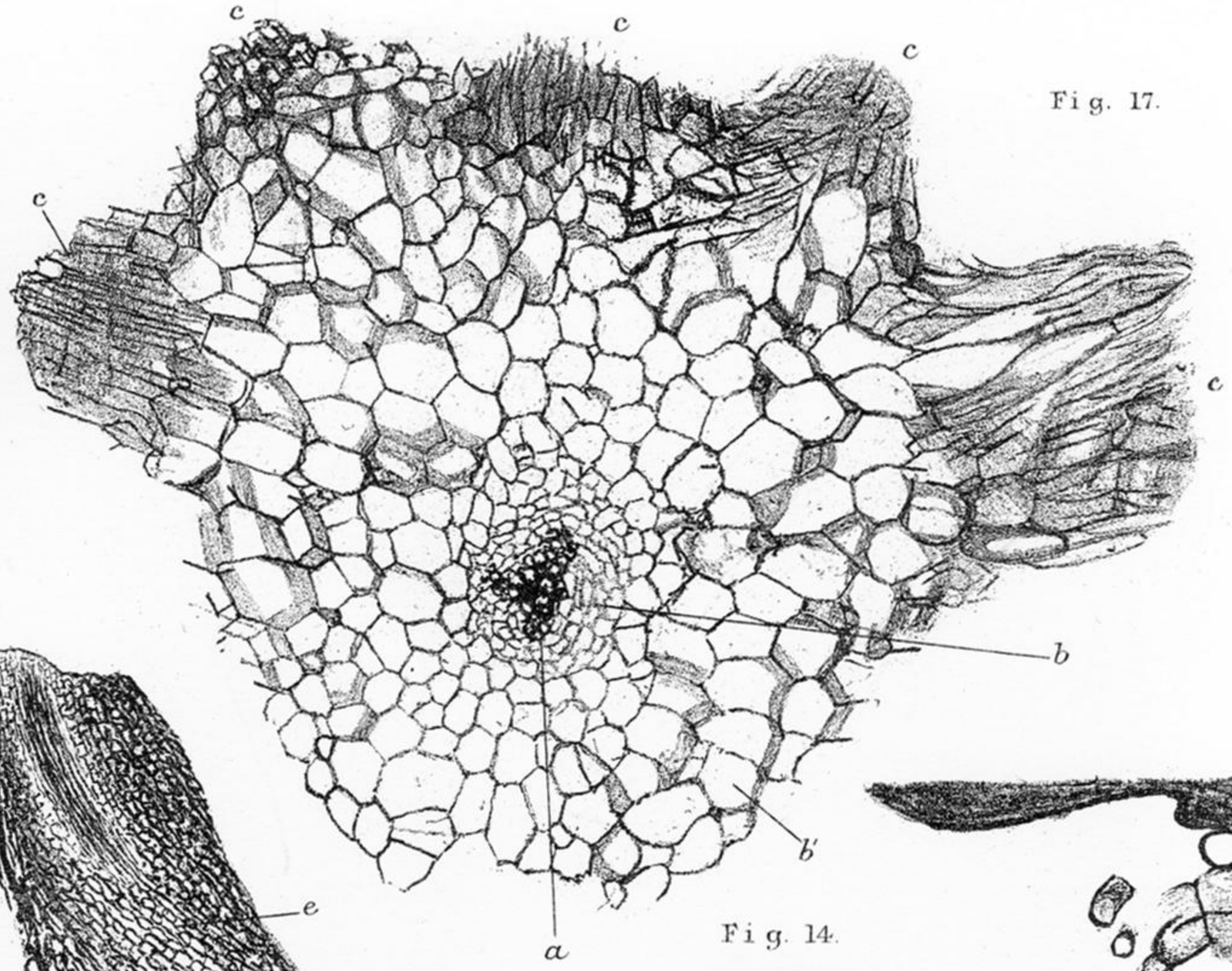

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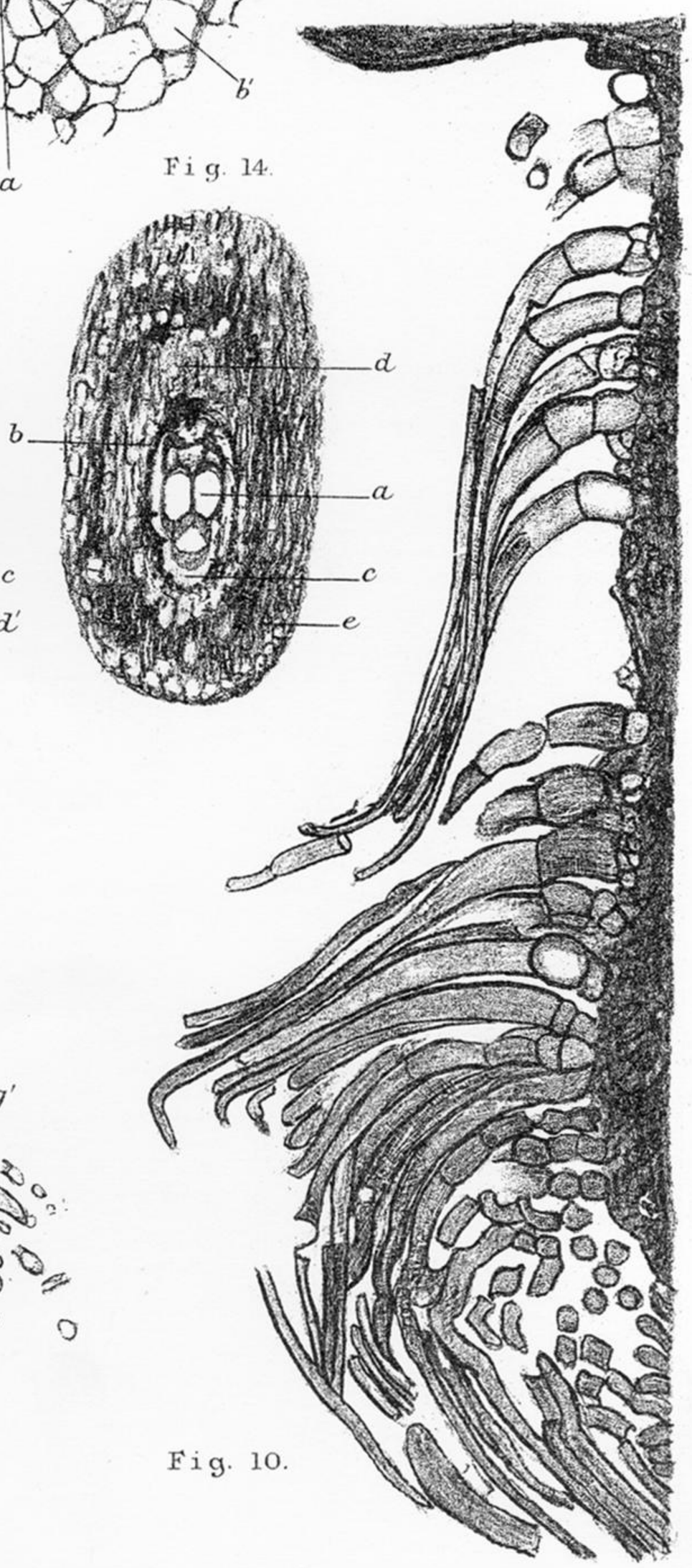

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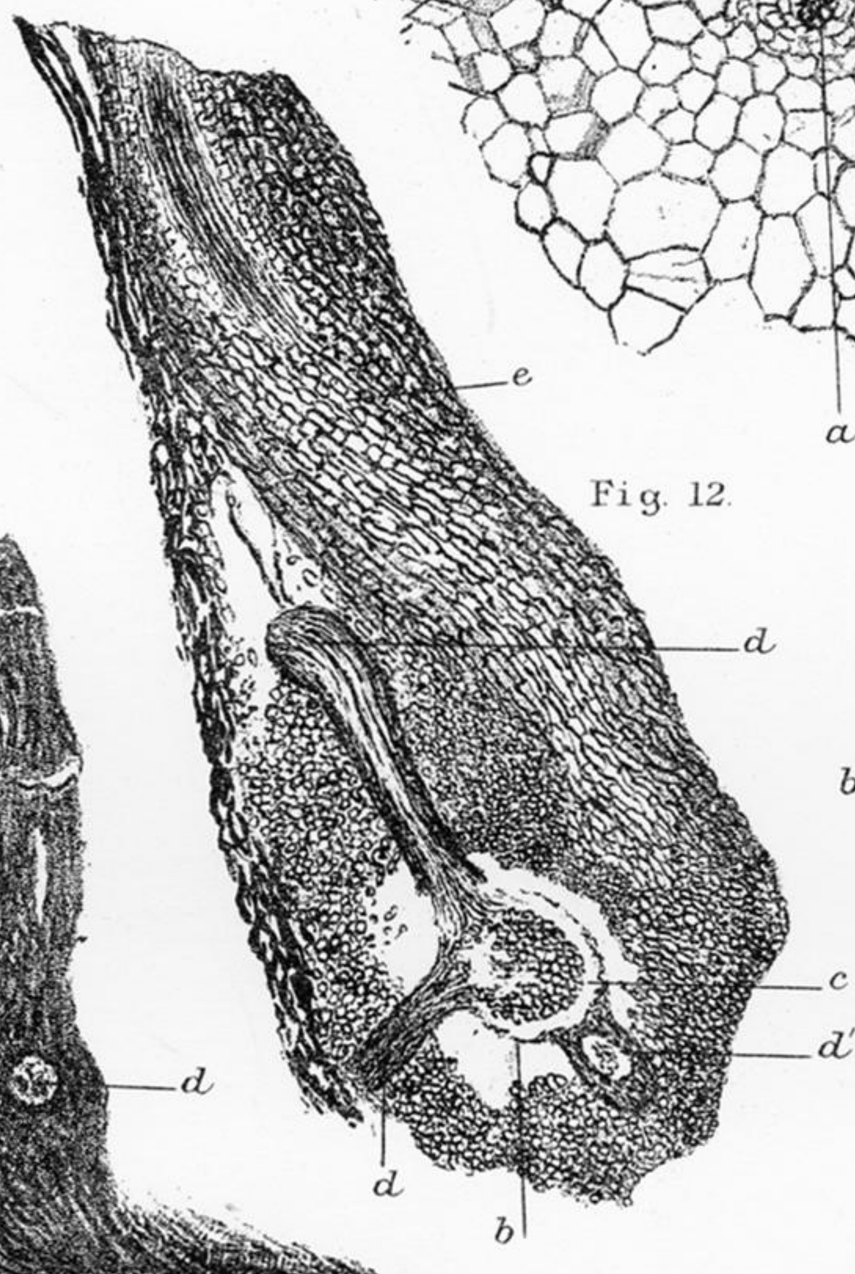

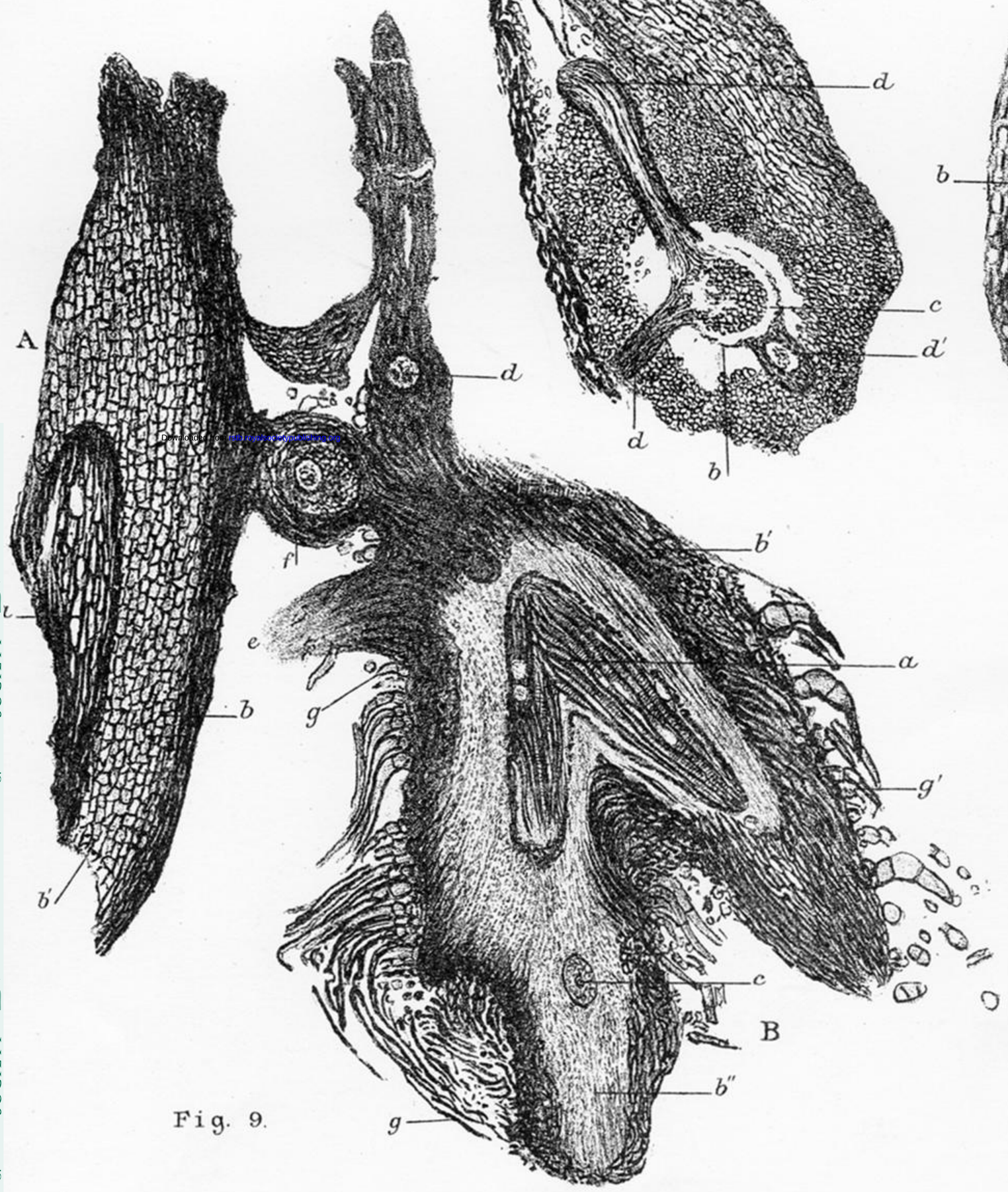

Fig. 9.

Fig. 10.

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